A COURSE OF CHEMISTRY,

DIVIDED INTO

TWENTY-FOUR LECTURES,

FORMERLY GIVEN BY THE LATE LEARNED

DOCTOR HENRY PEMBERTON,

PROFESSOR OF PHYSIC AT GRESHAM COLLEGE,

FELLOW OF THE ROYAL SOCIETY,

AND OF THAT AT BERLIN.

Now first published from the Author's Manuscript

By JAMES WILSON, M. D.

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MDCCLXXI.

PREFACE.

IN publishing these Chemical Lectures, I shall give some account of their author, in detached particulars, as they occurred to me, during our long acquaintance and friendship.

Doctor HENRY PEMBERTON *was born at London, in* 1694, *of honest and respectable citizens. He was of a middle stature, fair complexion, and serious aspect. This last did not arise from any gloominess or moroseness in nature; for he was of a mild temper and very free and easy in company; but from frequently meditating on some point of speculation. His senses were acute and delicate, especially that of hearing, whence he received great delight from music, which he indulged by fre-*

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quenting some operas and all Handel's oratorios. He early discovered a talent for mechanics, readily performing any manual operation, as making of fire-works, and effecting other contrivances not unbecoming an active and ingenious youth. He was generous, and so far from being envious, that he used to advise and encourage such as fell in his way endued with real genius. Besides he possessed an extraordinary faculty in distinguishing of things; consequently he reasoned always justly, not to be imposed on by a cloud of specious words, and in any dispute he was universally allowed to be in the right. To crown all, his mind was of the best disposition, he having the highest regard for honour and honesty; insomuch that during the very many years I was most intimately acquainted with him, which I esteemed as the greatest felicity of my life, I never knew him to offend against their strictest rules.

In his youth, his health being precarious, he was sent to a country grammar-school at Guildford in Surry; where, from his sagacity and diligence, he readily became master of all the

the learning, that place could afford. Here he met by accident with books on mathematical subjects, some on the practical parts, others on algebra. Upon these he made very pertinent observations, discovering a surprizing degree of invention in those sciences, which he thenceforward cultivated with great success.

Returning to London he read the higher classics with Mr. John Ward, a gentleman perfectly acquainted with whatever related to the knowledge of antiquity, who was afterwards professor of rhetoric many years at Gresham college, and doctor of civil law. His pupil thence received such an impression of the excellency of those writers, that he bestowed much time upon them, and with what success he has given proofs to the public. Now he met with Dr. Halley's fine edition of Apollonius's Conics, rejoicing that so large a volume was written on his beloved subject. This he read over with infinite delight. Nay in the course of his life he had read it over thrice; solving the problem to four lines according to the strictest intent of the ancients, which was

published a long time after in the Philosophical Transactions(a).

As he designed for the profession of medicine, he repaired to Leyden, in order to attend the colleges, as they are there called, of the famous professor Boerhaave.

Here a gentleman lent him sir Isaac Newton's Principia, which was then prodigiously scarce. But great was his surprize, when, contrary to what he had so often heard, he found that book written in a most clear manner; so that he went through it without the least impediment. He no less admired the discoveries made in the optics, and sir Isaac Newton's manner of treating the quadratures. From the introduction to that treatise, he acquired a true idea of the methods of prime and ultimate ratios, and of fluxions, which was afterwards in 1735 *published in Mr. Robins's discourse on those subjects. In the enumeration of the lines of the third order he deduced the equations most readily and without any ambages.*

(a) Vol. 53. 1763.

Here

Here he met with Dr. Halley's edition of Apollonius de Sectione Rationis, which he could not sufficiently value; as thence he became acquainted with the geometrical analysis of the ancients, which he much valued, and afterwards frequently practised.

He also solved the problem the foreign mathematicians had with some sort of insult proposed to those of England.

His modesty and backwardness of putting himself forwards made him little taken notice of, but an accident procured him much fame. The professor, among other his colleges, gave one upon the subject of vision; here he committed many mistakes in the science of optics: of these our young geometer modestly informed him in a letter. The professor, far from taking this amiss, every where spoke of it with the highest commendation, boasting of his having so great a genius for his pupil, and frequently consulting him about some point in the Newtonian philosophy.

Hence he went to Paris to perfect himself in the practice of anatomy, to which he readily attained as being dexterous in all manual

operations. Now there happened a lucky accident; for the large library of the abbé Gallois was sold by auction. Among other books there was almost a complete set of mathematical ones, both ancient and modern. Hence he furnished himself with good store. In perusing this treasure he chose to begin with originals. Of these he admired Lucas Valerius's (an author now unregarded) determination of the center of gravity in solids. Of this he a long time after informed sir Isaac Newton, who allowed it to be most elegant.

Though Dr. Halley had asserted, that Robert Anderson first shewed how from an eminence to strike an object, yet this is in Torricelli. Among the books there was a tract in 4to, intitled De novis Spiralibus Exercitationes duæ, &c. Authore P. Petro Nicolas Tolosæ, 1693. This he read with great pleasure, as the demonstrations proceeded not inelegantly on prime and ultimate ratios. Now he improved Huygen's solution of Alhazen's problems, which was published in Mr. Robins's Remarks on Dr. Smith's Complete System of Optics. Afterwards he performed

formed what was much more difficult in giving the determinations of that problem(b).

On perusing Regiomontanus, Vieta and other writers on trigonometry, he made several improvements in that useful branch of the mathematics; some of which have been published very many years after in our Philosophical Transactions (c).

He also made a collection of curious problems, which he solved by the ancient analysis, intending to write on that most elegant, though neglected subject.

In his return to London, he happened to shew Dr. Keil his solution of the foreigner's problem, with which the doctor was so pleased that he immediately carried its author to sir Isaac Newton, believing the good knight would be glad to find there was so promising a genius. But sir Isaac Newton then took no further notice of our young geometer, which was a great detriment to them both, as after-

(b) In the appendix to the second volume of Mr. Robins's Mathematical Tracts, printed in 1761, p. 303.

(c) Vol. 51. part 2d. 1760. Among his papers is a short history of trigonometry from Menelaus to Neper.

wards

wards appeared. This coldness was believed to proceed from some ill offices done by a malevolent person, who then had sir Isaac's ear.

Now he became acquainted with Dr. Mead, to whom he had been before recommended. He also attended very assiduously St. Thomas's Hospital, lodging with a relation, an apothecary, in order to be acquainted with the London practice. Though he thus made himself perfect master of all the branches of physic, he rarely practised it, owing to the fickle state of his health.

In 1719 he returned to Leyden, there to take his doctor's degree. The professor Boerhaave retaining a great esteem for him, obliged him to lodge at his house during his abode in that place. The question maintained in his thesis was, By what power is the eye enabled to discern distinctly objects at different distances. This is determined to be owing to a change made in the chrystalline humours. The demonstrations there used, he afterwards rendered much more elegant, which he intended to publish in another edition.

He

He became ſtill more familiarly acquainted with Dr. Mead, to whom he was greatly aſſiſtant in the doctor's writing on the plague, eſpecially in the eighth edition of the book, in which all the objections that had been raiſed were ſo thoroughly anſwered, that no more ever appeared.

The firſt ſpecimen he gave the public of his ſkill in what they call the ſublime geometry, was by accident. Seeing at a bookſeller's ſhop in one of the Acta Eruditorum, a problem propoſed as very difficult by Mr. John Bernoulli, he immediately ſolved it. The ſolution was publiſhed without his name in the Philoſophical Tranſactions, No. 372. Ann. 1722, and afterwards amongſt the collection of M. Bernoulli's works. But the ſolving of theſe kinds of barren problems he looked upon with ſir Iſaac Newton to be no better than cracking pebbles. Then Mr. profeſſor Smith of Cambridge advertiſing, that he would reprint Mr. Cotes's Logometria, adding other works of that excellent perſon; Dr. Pemberton in converſation obſerved to him, that Mr. Cotes had given an indiſtinct idea of ratios, and whatever

ever may be done by what he calls their measure and that of angles, might be effected by the means of the circle and hyperbola. The professor not only denied this with warmth, but in the preface to Mr. Cotes's works, printed in 1722, admonished the doctor, but without naming him, to lay aside all prejudices, and to consider these things more attentively. Upon this the doctor, in an epistle to me, proved what he had advanced, demonstrated Mr. Cotes's excellent proposition, which the professor had not done, and solved the thirteenth problem of the third book of the Principia by a conic section, of which sir Isaac Newton has taken notice in the last edition.

As he desired nothing more than to be acquainted with that great man, he was composing, to bring this about, a treatise giving a familiar account of sir Isaac's discoveries in philosophy. But an unforeseen accident effected this most completely.

Signor Poleni produces an experiment, which, he thinks, establishes beyond contradiction the truth of Mr. Leibnitz's notion of the force of moving bodies. Dr. Pemberton

wrote

wrote a paper containing a full confutation, which Dr. Mead shewed to sir Isaac Newton. The knight was so well pleased with it, that, as great a man as he was, he condescended to visit the doctor at his lodgings, bringing along with him a confutation of his own grounded on other principles. Both these were immediately printed in the Philosophical Transactions, No. 373, An. 1722. Hence followed a free intercourse between these two persons, whose conversation turned upon mathematical and philosophical subjects. Sir Isaac Newton was one of the modestest men in the world, so that he even solicited Dr. Mead to prevail on Dr. Pemberton to assist him in making a new edition of the Principia.

But in the mean while Dr. Langwith, describing in the Philosophical Transactions, No. 375, An. 1723, an appearance in the rainbow not yet taken notice of, Dr. Pemberton accounted for it, and gave by the ancient analysis two solutions relating to the rainbows, the last containing that of a solid problem.

Again Dr. Mead published in 1724 a pompous edition of Cowper's Muscles: to this was pre-

premiſed a moſt elaborate diſſertation, written by Dr. Pemberton, on the actions of thoſe of the human body. Here was ſhewn the error Mr. John Bernoulli committed in determining the figure of the cells into which he imagined each fibre of a muſcle was divided. Mr. Bernoulli replied, and heedleſly attributed the diſſertation itſelf to Dr. Mead. It contained proofs of the moſt profound ſkill in anatomy and geometry; the demonſtrations were alſo grounded on prime and ultimate ratios.

But now the edition of the Principia was entered upon. As the doctor lived a great diſtance from the author, he moſtly ſent him letters from time to time, containing obſervations on the book. Theſe were received with the utmoſt goodneſs, and accordingly many alterations were made, more were intended, but prevented for want of time. In particular his friend Dr. Brooke Taylor informed him, there was a miſtake in relation to the preceſſion of the equinox, and ſhewed how to rectify it. Dr. Pemberton for his care was rewarded moſt nobly, according to the natural generoſity of the author, which even old age could not in

the least diminish. But besides, what the doctor still more valued, in the preface he is said to be "Vir harum rerum peritissimus." The omission of the scholium, that mentioned M. Leibnitz, was highly resented by the foreigners; but of this I have spoken elsewhere(d). *One author indeed* (e) *has had the hardiness to insinuate, it was omitted without Newton's consent. Now I am a witness, that he ordered it to be left out, and the new scholium to be substituted in its place, which was intirely composed by sir Isaac Newton, and printed from his own hand-writing.*

Dr. Pemberton thought now a proper opportunity offered for publishing his abovementioned treatise, which he begun to read to sir Isaac Newton, who highly approved of it. But he died suddenly; however the book was printed in 1728, *by a very numerous subscription, with the title of A View of Sir Isaac Newton's Philosophy. In the preface he mentions his connection with that great man, and*

(d) In the above-mentioned Appendix, p. 327.

(e) Histoire des Mathematiques par M. Montucla, à Paris, 1758, vol. ii. p. 338.

gives

gives his opinion of the mathematical writers sir Isaac Newton most esteemed. As that work by the manner of publishing it fell into the hands of great numbers, who could not have the least idea of what it treated on, they expressed themselves dissatisfied with it; but it must be owned, to be an excellent performance, and to answer fully what the author proposed. It has been translated into Italian and French.

He would have published Newton's Treatise on Fluxions, but the owners of the copy asked more money, than the booksellers cared to advance.

Then the doctor advertised he would publish a comment on an English translation of the Principia; and I find in his copy a great number of papers written for that purpose; but a translation very suddenly appearing, hindered him from executing that design. And indeed he began to grow weary of mathematical speculations.

When king George the second visited the university of Cambridge, the doctor had there an honorary degree of doctor in physic conferred upon him.

Being

Being chosen professor of physic at Gresham College, he undertook to give a Course of Chemistry, which was improved every time he exhibited it. This was universally applauded; insomuch that the college of Physicians engaged him to review their Pharmacopæia, in order to make a new edition, purged intirely of every trifle, that had so long disgraced it.

For this purpose a committee was appointed. And the doctor made experiments on the prescriptions, and drew up two plans, containing reasons for the intended alterations. Accordingly the Pharmacopæia corrected came forth. The college not doubting but it would be put into English, desired the doctor to undertake that task. This he performed, premising a narrative, and adding remarks on most of the prescriptions, being the substance of the plans he had laid before the college. Hence it appeared, how well he was acquainted with pharmacy, and how mean an opinion he had entertained of most of the writers on that subject.

I mentioned the doctor's readiness to assist any one of parts. How he behaved to Mr. Robins I have largly declared in the preface to the latter's Mathematical Tracts.

About the same time was recommended to the doctor a young gentleman, Mr. Glover, just come from school. As he was indued with a disposition and capacity to succeed in any kind of study whatever, the doctor advised that of the mathematics, informing him of the most genuine authors; and also to perfect himself in Greek. The branches of the mathematics proper for a gentleman to know he readily learnt, with thoroughly comprehending their nature, and perceiving the force of the manner of reasoning used in those sciences; in time he rendered himself master of the Greek, and of the authors written in that copious language. But Mr. Glover possessed besides an extraordinary talent for poetry, and from verses he had early composed, was formed the admirable poem of Leonidas. This being published in 1738 (f), *the doctor, who*

(f) In 1770 came out a fifth edition augmented.

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entertained particular notions about this subject, took an opportunity of printing them in a pamphlet, (g) *intitled Observations on Poetry, especially the Epic, occasioned by the late Poem upon Leonidas. This shewed the great judgment and learning of the author, and it was received by the public with singular approbation, no objection having been ever made to what was there advanced. Abroad a writer of a literary journal having given an account of the doctor's pamphlet adds, "Ceterum auctor de epico et tragico carminis genere rationem ducem fideliter secutus est* (h)."

The poem of Leonidas procured Mr. Glover to be a great favourite with lord Cobham, and consequently to be well known to his lordship's nephews and their acquaintances. To these Mr. Glover recommended Dr. Pemberton, whom they honoured by bespeaking and attending a course of his chemistry. As these were the patriots of the times, the doctor, having thoroughly considered the writings of

(g) The author has left a copy with additions.

(h) Nova Acta Eruditorum, Octob. 1747, p. 598.

Machiavel, Harrington, Nevil and others, drew up a plan of a free ſtate with a king at the head. This was much admired by ſuch as had read it; and many years after his friend Dr. Brockleſby preſented a copy to the late right honourable Charles Townſend chancellor of the exchequer, who ſo well approved of it and its author, as to eſpouſe his cauſe when the city thought fit to demoliſh Greſham college; but I do not find a copy of it among his papers.

Mr. Weſt being about publiſhing his Tranſlations of Pindar, the doctor preſented him with a ſuccinct account of the ancient ode, which was printed in the preface, where the author ſtyles him his learned and ingenious friend.

Though he had diſcontinued all mathematical purſuits, yet he was drawn on Mr. Robins's account into a controverſy about fluxions. But of that I have ſpoken in another place (i).

For many years paſt he had accuſtomed himſelf to ride with ſome agreeable friend

(i) In the above-mentioned Appendix.

every

every summer for his health's sake over different parts of the kingdom. Here he took an opportunity of visiting our mines and the shops of our workmen, as appears from his Course of Chemistry.

During the neglect of mathematical studies, he used to amuse himself with composing on various subjects; for he never could be idle, whilst he enjoyed any tolerable degree of health. On our attempts to alter the style, he wrote a learned dissertation on that affair. But in my opinion much need not be said on a thing so obvious. The beginning of the year should be on the shortest day, but it being now fixt, it must stand as at present. Clavius has defined exactly enough its length. The consideration of the moon ought to be intirely laid aside, as its motion and that of the sun are incommensurable, and therefore never can agree. Besides here the moon is quite useless, having no relation to the seasons. It was at first introduced through mere ignorance, and continued through superstition. The moveable feasts, we make to depend on its motions, may be properly fixt in some part of those months, which they seem originally

ginally designed to occupy. Again a project was offered for reducing our weights and measures to the same standard throughout the nation. Accordingly a committee was appointed, and a long narrative published for this purpose. But it abounded with so many mistakes and absurdities, that the doctor was prevailed on to write on the subject. This being a very intricate affair took up much time; and I believe he never perfectly finished what he intended.

On his present majesty's accession to the crown, Samuel Martin, esquire, procured the doctor a pension, and that in the genteelest manner, without giving him before-hand the least hint of any such design. Mr. Martin had been one of the doctor's travelling companions, and well acquainted with his merit.

Now he very much contracted his acquaintance. Dr. Letherland, who possessed so fine a taste in geometry and polite learning, and Matthew Raper, esquire, were of ancient standing; but the first was dead, and the other resided generally at his seat in the country. So the doctor confined his constant visits to his beloved niece's family, Mr. Glover and his friends,

friends, together with ſome worthy merchants in the neighbourhood, where the time was paſſed moſt agreeably on all ſides.

But ſome years before, being attacked with a violent fever, which terminated in a defluxion on the leg, whilſt he was under the ſurgeon's care, his inclination for the mathematics revived, and he compoſed a diſſertation on eclipſes, which had like to have been publiſhed in the Philoſophical Tranſactions, but was prevented by an accident.

He began to print ſeveral diſſertations on mathematical ſubjects. One was on the Loci Plani; the reſt I have already mentioned. He would have gone on ſo to do, had he not been prevented by death; he was preparing for the preſs a ſolution of all the caſes with their determinations of the ancient problem de inclinationibus, which was a performance of his youth.

But in 1770 he was ſeized on by a moſt violent diſtemper, which, his friend Dr. Reeve thought, proceeded from an obſtruction in the gall-bladder, and indeed the patient was covered all over with a jaundice hue. Out of

this he unexpectedly recovered; the yellowness intirely disappeared, and he seemed thenceforward to be more hearty and of better spirits than ever. However, in March, 1771, he was attacked by the same distemper, which carried him off in two days time, to the grief of all who had been happy in his acquaintance.

His fortune, which was considerable, he left to a very worthy gentleman, Mr. Henry Mills, who is married to his niece, by which amiable person he has issue two sons, both of age, in perfect health and strength, very sober and diligent in business.

Among his papers were many mathematical ones; as demonstrations of the spherics and spherical projections, enow to compose a treatise on those subjects; a dissertation on Archimedes's skrew; improvements in gageing; to find in a given latitude the point that ascends the slowest of any in the ecliptic; to find in the ecliptic an arch of a given length, which will be longer in rising than any other arch of the same length; to find when the oblique ascension differs most from the arch to which it belongs; the principles of Mercator's and middle

dle latitude sailing; to find the heliacal rising of a star; to compute the moon's parallax; to determine the course of a comet through a parabolical orbit; with others, all most elegantly performed.

The Course of Chemistry he intended to improve by making farther experiments, and to change its form; which caused him never to publish it in his life-time. But he was by various accidents prevented from prosecuting his purpose. However, though it wants the advantages it might have received, I now print it from the original manuscript, believing, that all lovers of the art will be pleased to find here its operations explained on genuine principles.

As he used to deliver out schemes containing an account of the design and the contents of his courses, I have here printed one of them, altered in some things, in order to accommodate it to the last review he made of his lectures.

JAMES WILSON.

London,
August 10, 1771.

A SCHEME FOR A COURSE of CHEMISTRY.

THE design of this Course is to explain both the practical and philosophical part of chemistry.

In relation to the first will be exhibited the preparation of all the chemical medicines in present use, with an explanation in particular of the regulations now established by the college of physicians in their new dispensatory: also the smelting, refining, and such like processes on metals; together with other operations in those trades, or employments, which depend upon the principles of chemistry.

In all these it is proposed to describe in the plainest and fullest manner the method of proceeding in each operation, and to deliver the cautions necessary to be observed in them.

With regard to the philosophical part of chemistry, the practical processes are disposed in such

ſuch an order, as may be moſt conducive towards ſhewing the reaſon, and true effects of each operation; and ſuch others are added, as are requiſite for explaining the diſcoveries, which have hitherto been made in nature by chemiſtry, beſides ſome attempts towards farther advances.

In the progreſs of theſe experiments will be given an account of the eſſential difference between animal, vegetable and mineral ſubſtances; of the nature of nutrition, vinous fermentation, and putrefaction; of the nature and different operation of menſtruums, wherewith bodies are diſſolved; of the nature and operations of the air, how aqueous vapours and clouds are ſuſpended in it, by what means it cauſes bodies to burn; and why it is preyed upon by them in burning; how air is generated in fermentations and diſtillations.

In general it will be ſhewn to what principle bodies owe the conſervation of their diſtinct forms, and what powers procure thoſe changes, whereby the face of nature is perpetually varied and renewed.

The ſubject of each lecture follows.

PART I.

Of chemiſtry, and its operations in general.

LECTURE I. p. 1.

The threefold deſign of chemiſtry; the production of metals, the improvement of medicine, and of natural philoſophy. The riſe, and progreſs of the art.

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LECTURE II. p. 16.

The nature of heat explained upon sir Isaac Newton's principles, and the doctrine confirmed by experiment.

LECTURE III. p. 37.

Of chemical operations, and the requisite instruments in general. The division of the operations of chemistry into analysis and composition. Concerning volatility and fixity, and the difference between distillation and sublimation, with the instruments of each. The instruments for melting and calcining. Of digestion, and its instruments. Of lutes and hermetical sealing, with the method of cutting off the superfluous parts from glasses. The various kinds of heat; that of water, of sand, the open fire, and the two kinds of the reverberatory fire, with the furnaces for each of these heats: also the blast and wind furnaces; as likewise the athanor for continuing an equable degree of heat any length of time without intermission, and with small attendance; also Vigani's ex tempore furnaces composed of loose bricks only, to be set up and taken down at pleasure, wherewith all the operations of chemistry may be commodiously performed by those, who have not a fixt laboratory. Of the several sorts of fewel. Of clays and bricks, particularly Windsor loam, and the Stourbridge clay. Of the several sorts of weights.

LECTURE IV. p. 63.

Of chemical analyſis in general. The chemical principles produced by the analyſis of bodies enumerated. In particular of water; why it dilates in freezing; experiments with freezing mixtures, and the cauſe of their operation conſidered. Of ſalts and ſpirits; the acid, alkaline, and neutral; the criterions, whereby to diſtinguiſh acids and alkalis. Of oils, and their inflammability: burning conſidered, with the office of the air in it illuſtrated by experiment; alſo why water extinguiſhes fire. Of earth, the fifth principle. Of the aerial vapour ſeparated from bodies by diſtillation.

LECTURE V. p. 82.

Of chemical compoſition in general. Of menſtruums; their action explained; why heat promotes it; experiments on the heat and cold produced in mixtures and diſſolutions, and the cauſe thereof conſidered: concerning precipitation and cryſtallization. Why ſalts ſhoot in different figures.

PART II.

Of animal and vegetable ſubſtances.

LECTURE VI. p. 95.

Animal and vegetable ſubſtances analyzed by diſtillation; whereby all of the animal, and ſome of the vegetable are ſhewn to produce an

alkaline ſpirit, and ſalt, beſides an oil; the reſt of the vegetables containing an acid ſpirit with an oil; all leaving a black coal to be farther examined hereafter. Milk and urine conſidered particularly, and experiments made with the phoſphorus of urine. Charcoal how made. The aerial vapour collected.

LECTURE VII. p. 106.

THE purification and farther analyſis of the ſalts, ſpirits, and oils of the preceding lecture. How oils are ſeparated from watry liquors. The diſtillation of the natural balſams exemplified in turpentine; whence roſin, both yellow and black: how turpentine is gathered, and how tar and pitch are made. The diſtillation of eſſential oils: why theſe oils and reſines riſe ſo freely, while other oils lighter than ſeveral of theſe can be obtained only by expreſſion. The ſublimation of benjamin and camphire.

LECTURE VIII. p. 122.

THE aerial vapour ariſing from animal and vegetable ſubſtances in diſtillation farther conſidered. The effects of burning animal and vegetable ſubſtances in the open air: the fixt alkaline ſalt of vegetables prepared; Tachenius's method; how pot-aſhes and pearl-aſhes are made: ſoot diſtilled. Reflections on what hath preceded.

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LECTURE IX. p. 136.

On fermentation and putrefaction. What relation ſweetneſs bears to vegetable fermentation: here ſugar diſtilled: fermentation deſcribed in its whole progreſs to the making firſt of beer and wine, then of vinegar; and the nature of this operation inquired into: the inflammable ſpirit diſtilled from wine, and farther purified; of rectified and proof ſpirits, with the method of examining the ſtandard of ſpirits: vinegar alſo diſtilled: the original of tartar, and other eſſential ſalts; the purification and diſtillation of tartar; cream and cryſtals of tartar. How fermentation may be ſtopt or promoted. The effects of putrefaction; whence animal digeſtion explained.

LECTURE X. p. 154.

Compositions from the productions of the preceding analyſis conſidered; and the firſt of the compoſitions by the ſpirits and ſalts: here fixt alkaline ſalt run per deliquium, as it has been commonly ſtiled: alſo ſpirit of wine rectified by theſe ſalts. Theſe ſalts fermented both with the acid of vinegar, and of tartar; whence the ſal diureticus of the preſent diſpenſatory, and tartarum ſolubile. The effects of the acid of vinegar on coral, and the like terreſtrious ſubſtances. Magiſtry and ſalt of coral.

LECTURE XI. p. 161.

Compositions by the means of oils and vinous ſpirits. Soaps a compoſition of oils with fixt alkaline

kaline salts: soap of tartar: why these salts cause a sudden separation of the volatile salt from fresh urine. The tincture received by spirit of wine from these alkaline salts considered. The solution of essential oils and volatile resines by spirit of wine: tinctures drawn from vegetables by wine and its spirit; here extracts and resines.

PART III.

Of FOSSILS.

LECTURE XII. p. 169.

Of the fossil and similar salts; of sea-salt, nitre or salt-petre, alum, vitriol, and borax; their crystallization. These salts considered particularly. Their distillation, and rectification of their acid spirits. The calcination of vitriol. Its oil. Glauber's sal mirabile. A false tartarum vitriolatum. Aqua regia and fortis. The dying of scarlet. Why Glauber's spirit of sea-salt and of nitre smoke incessantly; and why acid of vitriol exposed to the air increases in bulk. Here occasionally how vapours are raised, and why condensed into clouds. How each of the fossil salts is obtained originally.

LECTURE XIII. p. 187.

Salts farther considered. The effects of the acid spirits of the preceding lecture on one another, and on other bodies: these acid spirits fermented with the fixt alkaline salt of vegetables,

and what ſalts are thence produced; here tartarum vitriolatum: the like experiments with the volatile alkali; here the compoſition of ſal ammoniac, with its ſublimation; the earthy part of all theſe ſalts, except nitre, precipitated by alkaline ſalts; whence ſome light into the nature of nitre: the fixt alkali more powerful than the volatile; hence the decompoſition of ſal ammoniac by a fixt alkaline ſalt, the ſpirit of ſal ammoniac. The purification of animal ſalts by ſpirit of ſea-ſalt, and ſalia volatilia oleoſa. The nature of the pigments made with alum: the Pruſſian blue here prepared, and ſhewn why a large quantity of this coloured terreſtrious ſubſtance is produced from two tranſparent liquors: the uſe of alum in dying. The detonation of nitre. Nitre increaſes the inflammability of bodies. The effects of the phoſphori explained, and what part of the air aids the burning of bodies. The acid ſpirits diſpoſſeſſing one another; the acid ſpirits dulcified by ſpirit of wine. The ſpiritus vini ætherius introduced by Frobenius. Here explained why ſpirit of wine reſtrains the fermentation of vinous liquors. Why the ſerum of the blood and whites of eggs are coagulated by heat, and the difference between the fat of animals and the oils of vegetables conſidered. The effects of the acid ſpirits on oils and camphire.

LECTURE XIV. p. 201.

Of mineral ſulphurs. Whence common brimſtone obtained. Here the general definition

tion of ſpars; and of mundics, otherwiſe called pyrites or marcaſites. Common brimſtone decompounded; whence ſpiritus ſulphuris per campanam, and the aqua ſulphurata of the preſent pharmacopœia: why the ſmoke of brimſtone checks vegetable fermentation: how bitumina differ from ſulphur: ſulphur not to be analyzed by ſimple heat, ſubliming intire into flowers: ſulphur diſſolved in oils, and by the help of fixt alkaline ſalts in water: here the balſama ſulphuris, and hepar ſulphuris. Magiſterium ſulphuris. Sulphur fulminated with nitre; whence ſal prunellæ, and ſal polychreſtus; the compoſition of gun-powder. The uſe of corning gun-powder. Pulvis fulminans. The general ſtructure of rockets, bombs, granadoes, and other fire-works, with the reaſon of their effects. Homberg's phoſphorus made. Orpiment here conſidered, and that ambiguous ſubſtance amber.

LECTURE XV. p. 216.

On ſtones. Gems. What ſtones will make glaſs, and how the operation is performed; why glaſs, when melted, is wrought by blowing, whereas melted metals are caſt in a mold. On lime: plaiſter of Paris. Phoſphorus of alum accounted for: aqua calcis: the acrimony of fixt alkaline ſalts, improved by lime into a cauſtic; whence lapis infernalis and the other common cauſtics in ſurgery: the action of lime on ſal ammoniac, whence ſpiritus ſalis ammoniaci cum calce. Mr. Boyle's fuming liquor with ſul-

ſulphur, lime, and ſal ammoniac: ſympathetic ink with lime and orpiment. The uſe of lime in making ſoap; here ſoap, both hard and ſoft, prepared: the uſe alſo of lime in making and refining ſugar: ſulphur diſſolved by lime; whence ſulphur precipitatum, commonly called lac ſulphuris. The phoſphorus of Balduinus deſcribed.

PART IV.

METALLURGY.

LECTURE XVI. p. 231.

GENERAL character of metals, perfect and imperfect. The calcination of the metals. How lead, tin, copper, iron, and quickſilver are calcined by our fires; whence from lead minium. Silver and gold not reducible to a calx but by burning-glaſſes. From quickſilver mercurius calcinatus, uſually called precipitatus per ſe; alſo from lead, litharge. From lead and tin together the powder called putty, wherewith metals are poliſhed; how this differs from the putty of the glaziers. Lead is uſed in plaſters. From iron, crocus martis aperiens; from lead, vitrum ſaturni and flint-glaſs. The manner of glazing earthen wares here deſcribed. The particular phænomena in the calcining of metals by the burning-glaſs. How calcined metals may be reſtored. Spelter ſhewn to flame upon melting. The cauſe of calcination, and of ſuch reſtitution.

LECTURE XVII. p. 249.

THE action of the acid ſpirits upon metals. Thoſe of nitre and ſea-ſalt ſuffice for diſſolving all metals. Theſe ſpirits ſometimes corrode the metals into powder only, ſometimes diſſolve and convert them into a ſalt capable of cryſtallization, whence the lunar cauſtic. The precipitation of diſſolved metals, hence aurum fulminans, mercurius precipitatus albus. How gold is refined from ſilver. By oil of vitriol diſſolving iron, is made ſal martis; by corroding quickſilver, turbith mineral. Hence alſo vitriol of iron, and oleum martis per deliquium. Tin diſſolved in vinegar produces ſal jovis. From lead and vinegar, ſaccharum ſaturni. The making ceruſſe. From copper and vinegar, verdigreeſe. From ſpirit of nitre and quickſilver, mercurius precipitatus ruber and arcanum corrolinum. Filings of iron and tartar produce chalybs tartariſatus and Helvetius's ſtyptic. The action of theſe acid ſpirits on the imperfect metals, whence magiſterium biſmuthi.

LECTURE XVIII. p. 260.

THE action of ſolid ſalts upon metals. Here mercurius ſublimatus corroſivus, its uſe in refining gold. Mr. Boyle's perpetually fuming liquor. Mercurius dulcis. The cauſticum antimoniale, known by the name of butter of antimony, cinnabaris antimonii, oleum antimonii, mercurius vitæ, diaphoretic antimony, bezoar mineral, and the bezoardic ſpirit of nitre. From ſal ammoniac, flores ſalis ammoniaci martiales,

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or ens veneris, so called; aurum musivum or mosaicum. Here also the corrosion of the metals by sulphur; whence factitious cinnabar, and chalybs cum sulphure preparatus.

LECTURE XIX. p. 270.

The separation of metals from their ores, and the reasons of the several operations used for this end. Of the gold and silver ores of America, of the gold sands of Africa, and how the metal is there collected: how the same metals are obtained in Europe: how lead, tin, copper, and iron are separated from their ores by charcoal; and how lead, tin, and copper are separated by pit-coal. How the refiners melt, what they call the sweep. The several ores shewn, and also models of the several smelting-furnaces.

LECTURE XX. p. 285.

Of essaying, with the nature of the several kinds of flux-powders. Essays of the metallic ores performed.

LECTURE XXI. p. 294.

The separation of the imperfect metals from their ores. The separation of quicksilver from its ore, in particular from native cinnabar. How bismuth is smelted from its ore. How spelter is produced. Bath metal. The production of antimony, and operations on it; the glass of antimony, the calx commonly called diaphoretic antimony; reduced to the metallic form named regulus

gulus of antimony, crocus antimonii, regulus ſtellatus, and vinum emeticum. The antimonial cup. From the ſcoriæ, the golden oil of antimony. Gold purified by antimony. On arſenic, zaphor, and ſmalt. On the mineral called black lead.

LECTURE XXII. p. 304.

Of refining, ſeparating, and other preparations of metals. How gold and ſilver, are ſeparated from lead, and how refined by this means. Why melted glaſs ſticks to iron, though to no other metal. Litharge made. How the ſeparation of metals is performed at the mines, how by the refiners, and how in eſſays. How ſilver is got from lead, how ſeparated from copper ſo as to preſerve both metals.

LECTURE XXIII. p. 312.

Experiments and other operations on metals. Braſs and ſteel made. Steel hardened and tempered. Why ſilver and gold are alloyed: an account of our preſent ſtandard, with the changes it has undergone. Other mixtures; whence bell-metal; cannon-metal; the metal of organ-pipes; pot-metal; bronzes of all kinds; Bath metal; pewter; ſolders of all ſorts, and by what artifice ſolders are made to join to the metals; how iron and copper are tinned, and how ſilver wire is gilt; amalgamas; how glaſſes are foiled with quickſilver, and how water-gilding is performed.

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LECTURE XXIV. p. 331.

THE CONCLUSION.

General recapitulation with additional experiments. Here considered the two universal active principles in nature, the repulsive and attractive, and shewn that the first is owing to sulphur, and the other to the acid in bodies: and consequently, that the acid principle unites the parts of bodies, and preserves to each its respective form, unless an external acid is applied to the body under circumstances, whereby the body is broken, and a new compound succeeds. The nature of the air farther explained: that the air causes bodies to burn by the same principle as acid spirits corrode metals and other terrestrious substances.

The lecture concludes with some observations on the changes in the taste of bodies, on colours, and with an explanation of the nature of mineral waters.

A
COURSE of CHEMISTRY.

PART I.

LECTURE I.

Of the Rise of Chemistry, and its Application to Medicine.

THE operations in the galenical pharmacy are few and simple; but the chemical are more complex, requiring a greater variety, and a more artificial structure of instruments for its several processes.

In treating of this part of pharmacy, it is not only necessary to describe the operations, but to explain the principles upon which they proceed, and the philosophical deductions which may be made from them; for chemistry has not only

been cultivated by physicians, as adding to the stock of the more ancient medicaments, but for the insight it affords into the constitution of natural bodies; whereby it promises no small improvement of the physiological branch of medicine, by leading to a farther knowledge of the nature of our blood and humours, than could otherwise be obtained.

But, previous to the treating of both these uses of chemistry, it will be requisite to give some general idea of the art, and whence it first took its rise.

That all sensible bodies are composed of many different parts is evident, because they can be broke to pieces, and divided into very minute fragments, by the instruments of artificers. Accordingly, all mechanic performances consist in dividing, re-uniting, and varying the forms of bodies: nay, the operations of nature, by which all things subsist, through the alternate destruction and renovation of natural bodies, seem to be only a continual separating and re-composing the parts of matter, by the means of certain powers of nature fitted to that end.

Chemistry, according to the extent at present assigned to the art, is an artificial application of these natural powers, whereby to discover the nature of these powers, and in what manner they

act; as likewise, by the changes thus wrought on bodies, to find out their make and constitution, and also to form new productions useful in human life.

The two great branches of this last, which is the practical part of chemistry, are the preparing of medicines, and the treatment of metals.

In regard to the antiquity of each of these, I do not know, that the application of chemistry to physic can be traced higher than the learned times of the Arabians. In general, many of the present forms, under which medicines are usually administered, we owe to them; and to this day, retain many words in pharmacy derived from their language; such as, syrup, julep, lohoch, and the like, which are originally Arabic words.

Among the preparations of pharmacy in general, some only mix the medicine with such other substances as may preserve it from corruption, so that it may be kept a longer time fit for use; the intention of some is no more than to cover over and disguise the taste of such medicines as are disagreeable to the palate; but others separate a part from the gross material, whereby the medical part of the material being disunited from the rest, it may not only be taken with less reluctance, but may operate more forcibly, than when united with the rest of the com-

pound: moreover, the effect of such separated parts is oft times very different from the effect of the compound itself.

Decoctions in water are preparations where the juices are separated from the gross parts of the medicine by boiling; and this preparation has been in use from the earliest times: but, besides this simple method of separating the effectual from the inefficacious parts, the Arabians introduced other more artificial kinds of separation, for this purpose, by chemical operations.

The other branch of practical chemistry, which consists in the smelting and refining of metals, has been in use from the earliest accounts of time. Indeed, this is an art so necessary, that, till it was discovered, men could not have led any other than a savage life.

Though both these subjects are at present considered as the proper objects of chemistry, yet it must be confessed, that the art was very different in its original. The name of chemistry seems first to have made its appearance in the world with the ridiculous pretence of converting other substances into gold and silver. How ancient this fanciful scheme has been, or where it first took its rise, is not easy to determine. It certainly owes not its original to the Arabians; for it was undoubtedly among the Greeks some

ages

ages before they had any communication with that people. The name of the art occurs in Julius Fermicus, an author near the time of Conſtantine the Great; and within an age or two after, the ſcheme itſelf of making gold and ſilver, is mentioned, by other authors, as openly pretended to. And, on the other hand, Abul Farajius, an eaſtern writer, aſſures us, that, as the wandering Arabs were always deſtitute of arts, ſo thoſe who lived in fixed habitations, had no other ſubjects of literature among them, before the times of Mahometaniſm, than the ſtudy of their language, and poetry; they made no pretenſions to any ſubject of philoſophy whatever, not even aſtronomy; though, for the uſe of agriculture, they were obliged to obſerve the riſings and ſettings of ſtars; yet in this they confined themſelves merely to practical obſervations, without attempting to raiſe any aſtronomical ſyſtem upon them. Now, the earlieſt writers upon this art of gold-making always give themſelves the name of philoſophers in ſo high a ſtrain, as if they only were worthy of that appellation: they likewiſe ſpeak of their art, as of very great antiquity; but we have no writers upon it, that can with any reaſon be ſuppoſed prior to the tranſlation of the Roman empire from Italy to Conſtantinople; though there are

found, in ſome of the libraries of Europe, pieces with very ancient names prefixed, ſuch as of Democritus, and the ſtill much more ancient Ægyptian, Hermes. This has made ſome moderns fond of imagining the art to have been in Egypt from the earlieſt times: but theſe are credulous gentlemen, and proceed upon the ſuppoſition, that this piece of ſkill did really once exiſt; that the immenſe wealth thoſe people boaſted of to ſtrangers, was produced by this art; and even give ear to the tale, that Diocleſian, to hold, at laſt, this nation in ſubjection, was obliged to deſtroy their books of chemiſtry, in order to cut off a ſource of wealth, by which they were inſtigated and enabled continually to rebel; whereas it is extremely incredible, that ſo much as a pretence of this kind could have exiſted among that people, and not have come to the knowledge of the Greeks, while they were maſters of that country, however induſtriouſly the ſecret might have been concealed. If, therefore, this imaginary art did not take its firſt riſe among the Greeks, in the latter times of the empire, when learning and knowledge declined, as moſt probably it did not, I think we muſt look out for ſome other ſource whence to derive it. Travellers inform us, that this ſcheme has, for ſome ages at leaſt,

been pursued with assiduity by many of the people of the East; and the Romans began to have communication with the Persians even before the removal of the empire eastward, which, upon that nearer approach to them, must have encreased: by this means, therefore, they might become acquainted with this, and perhaps other fooleries of the eastern nations, with which, in the decline of arts, they themselves were captivated.

It does not appear, that the application of any chemical productions to medicine was attempted thus early; but the Arabians expressly applied chemical operations to this purpose. Though the absurd conceit of discovering, by the secrets of this art, one medicine that should be a universal remedy against all diseases whatever, is of a more modern date. If Paracelsus is not the first, he is the most eminent of the pretenders to this incredible secret; to which Van Helmont has added the farther extravagance of an antidote even against fate, and promises no less than immortality itself.

The first of these, Paracelsus, whom every true adept admires to this day, appeared at the time of that grand restoration of arts and learning, when science began to be delivered from the shackles put on the pursuit of knowledge

by the superstitious veneration for antiquity, which, till then, had been an effectual bar against improvements of any kind. At this time arose Vesalius, by whose labours in anatomy, the dictates of the ancient sages were brought to a just trial, whereby the formal doctrines of the schools, built on Aristotle and Galen, were found not so infallible as had hitherto been presumed; and from hence a genuine method of inquiring into nature was gradually introduced. At this time, Paracelsus also entered the lists, and declared open war upon the schools, disavowing, in the most opprobrious terms, the whole ancient doctrine, and the philosophic systems, by which these ostentatious superfluities were supported, to which all men had as yet implicitly subscribed. But nothing more rational, that should prevail with men to quit the dictates they had embraced from their earliest youth, could be expected from one of this man's character, which was perhaps the most absurd that ever imposed on mankind. From the age of five and twenty, his life was spent in drunken debaucheries with the most illiterate people*; his whole pretensions in physic supported by a daring and inconsiderate use, after the manner of more modern empirics, of some powerful medicines, (though, perhaps,

* Oporin. Epist. ad Solenandr. et Wier.

much

much fewer in number than is commonly pretended) in which it must be supposed he was sometimes fortunate; but probably much oftner unsuccessful, if he scrupled not to own to Oporinus, his admirer and follower, that he scarce ever could keep his practice in credit, above a year in any one place†. What kind of reformation he aimed at, may be judged of by the following specimen, where, in censuring the doctrine then in fashion, of appointing directors to guide medicines to the diseased part, he explains the matter thus: *Non enim eo modo medicina provehitur, sed seipsam promovet per virtutem suæ imaginis.** For example, eyebright has in itself the form and image of the eye: whence, when it is taken in, it passes to, and stops at its own member, and with the form of that member; so that the eyebright becomes entirely eye. In like manner, is contained the form of all the members of the human body in plants, stones, metals, and minerals.

Thus, though from this time the sciences in general began to be cultivated in a more rational manner than before, chemistry did not advance by the same degrees with the rest, from its

† Conring. de Hermetic. Medicin. l. ii. c. 13. ex Oporin. Epist.

* Labyrinth. Med. c. 8.

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* Oporin. Epiſt. ad Solenandr. et Wier.

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professors inlisting themselves under this madman, and rendering themselves ridiculous by labouring in earnest to find a meaning to such drunken ravings, and professing a veneration for one, who could assert the spleen, and even the kidneys, to be parts noxious to life, and ought to be destroyed; nay, could treat the idle tale of Fortunatus and his wishing-cap, as composed by good and holy men.

But, indeed, it has been the fate of chemistry to be, for a long time, chiefly cultivated by men so far removed from that sobriety of mind and judgment necessary both in philosophical and medicinal enquiries, that they have rather rivalled each other in extravagancies, he being most admired, who abounded in conceits the farthest removed from good sense. Of this no greater proof can be given than in Van Helmont, who advanced himself to become a dangerous rival in fame even to the great Paracelsus, by those dreams, and doting fancies, with which, in obscurity, he amused his rambling imagination, that render him no less an object of contempt, than the supercilious ignorance of the other merits our scorn and indignation.

These men's absurdities, as well as the ridiculous original of the art, would naturally prejudice men of understanding against it; but as it

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has at length been alſo cultivated by men of more ſober minds, it has ſurmounted theſe prejudices; and being found to have actually ſupplied us with many valuable remedies, a juſt diſtinction has been made between the art itſelf, and the follies of its profeſſors; and ſuch chemical preparations as are found to have real uſe in phyſic, are univerſally held in due eſteem, without being either extravagantly extolled by one ſet of men, or unreaſonably depreciated by another.

The purſuit after the philoſopher's ſtone, or the art of making gold, and the ſearch after the univerſal medicine, are now diſtinguiſhed from the more vulgar part of chemiſtry by the name of alchemy; and it is highly proper, that ſuch extravagancies ſhould be effectually diſtinguiſhed from what is uſeful, that while one is treated with the contempt it deſerves, the other may not loſe its eſteem in the minds of men.

But beſides the two uſes of chemiſtry already mentioned, that of preparing medicines for the uſe of phyſic, and that other, which relates to the metallurgic art, there is alſo a third purpoſe to which it has been applied; which is the improvement of natural philoſophy, and by its operations to gain a further inſight into the conſtitution of natural bodies. For this deſign, chemiſtry

mistry is abundantly fitted; for there is no way so obvious of coming at the knowledge of the structure of bodies, as by dividing them, and separating the parts of which they are composed, so that each part may be viewed and considered separately.

The first enquiry to be made into organical bodies, such as animals and vegetables, is by taking to pieces the organs of which they are composed, and to consider the several uses of each. Thus great progress has been made in the knowledge of animals by anatomy; and also a great insight gained into the structure of vegetables from such inquiries into their composition, as, from its similitude to what is done in the anatomy of animals, is usually called the anatomy of plants.

Thus is found, by what organs animals and vegetables are rendered fit to continue on their respective lives: but how the parts of matter, which frame these organs, are constituted and held together, is no part of this anatomy to teach; this is still a more remote enquiry; and in this chemistry promises no small assistance.

But it is not to be expected, that the fore-mentioned extravagant writers, whose thoughts were carried astray after those wild pursuits, of the making of gold and universal medicines, should

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be able to make any ſound diſcoveries in natural philoſophy: in fact, it appears, that, though they are very bold in their pretenſions, they are here alſo conſiſtent with themſelves, and have indulged the like idle dreams in their inquiries into natural cauſes.

This uſe of chemiſtry our countryman, Mr. Boyle, has cultivated in a manner that has done him and the art honour. He, at the ſame time that he practiſed in the art with great aſſiduity, has cenſured and confuted the vain reaſoning of preceding chemiſts with much freedom.

But above all, the immortal ſir Iſaac Newton muſt here be mentioned, of whom it appears, from his writings, that the art of chemiſtry was worthy a conſiderable place in his thoughts, and that he was very well acquainted with its operations. Nor did he cultivate it without ſome meaſure of the like ſucceſs, as he had in all the other ſubjects that employed his mind. He has given hints that, well improved, will open a way to make the greateſt diſcoveries in nature, by the means of this art. Not only his general proofs, drawn from chemical experiments, of ſome active principles exiſting in nature, by which all natural effects are cauſed; but his more particular thoughts, concerning the nature of acids, cannot be ſufficiently admired. If we do not

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rest satisfied in expatiating upon these general hints he has given us, but make that use of them, he intended, and consider them as guides to a more particular discovery of the nature and manner of operation of these powers, I doubt not, but at length some happy genius will arise, who shall open to our view a new and large field of discoveries. This I am the more emboldened to say, when I consider the discoveries this great man has himself made, not only in the larger system of the world, but also concerning the operations of nature in the small parts of matter. And as this latter part of his discoveries are made by the consideration of light, and the mutual action between it and bodies; so we are to take notice, that the operations of chemistry are principally produced by the application of heat, which is the great instrument that nature herself makes use of in all her operations, and appears always to accompany light in proportion to its quantity. And what should farther raise our expectations from experiments made by the application of heat and fire is, that heat is such a universal instrument of nature, that the light of the sun, by which all nature lives, sheds its vivifying influence by its power of producing heat.

As I design to pursue this Course of Chemistry in the method I judge most conducive to illus-

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trate the application of this art to natural philosophy, I ſhall begin with explaining, as diſtinctly as I can, the nature of heat; for, ſince the operations of chemiſtry are produced chiefly by heat, in order to judge of the changes wrought in bodies by chemical operations, it is neceſſary to know how heat operates, and what effects, in general, it is diſpoſed to produce in the ſubjects, whereon it acts: and this I deſign for the ſubject of our next meeting.

LECTURE II.

I Proposed, at the last meeting, to open our chemical processes with some considerations on the nature of heat.

The most conspicuous cause of heat is the sun; without whose beams, a universal cold would overspread the face of nature; all motion and life would cease; and the whole earth, with all things it contains, would become one dead mass of matter: but the sun, being also the great parent of light, it has been usual to speak of light and heat promiscuously, as if the immediate instrument of both were the same. However, it must be acknowledged, that they do not accompany each other constantly in the same proportion. I admit, that heat always follows light; and that the degree of this heat is proportional to the quantity of light: for though it is certain, that we often see light, where we feel no sensible heat at all, (such a light is the shining of the glow-worm, of rotten wood, of the foam of the sea, of the phosphorus, and the like) yet it must not be concluded, that these weak lights do not give a proportional heat, though it be insen-

ſible to us; for our organ of ſight is to be affect-ed by a very ſmall quantity of light. The light of the moon is greatly more ſenſible than any of theſe; and yet its quantity, upon com-putation, will be found to be exceeding ſmall.

The light of the moon is the rays of the ſun reflected from that planet to us; and what part of the ſun's light the moon receives, and how much the light reflected from the moon is ſcattered before it comes to us, may be com-puted without difficulty.

By this means might be compared the light we receive from the ſun with that we receive from the moon, if the moon reflected all the rays of the ſun which fall upon it; for then the greateſt light we can receive from the moon, when at the full, and alſo neareſt to the earth, will be exceeded by the light of the ſun more than 87,000 times. But if we ſuppoſe the moon to reflect but half the light that falls upon its ſurface (which is the moſt that can with any probability be ſuppoſed), then the light of the moon will be exceeded by the ſun's light more than 170,000 times; and in the mean diſtance of the moon from the earth, her light will be exceeded by the ſun more than 190,000 times. Some experiments have concluded it to be ſcarce two thirds of this.

Now, since the light of the moon is so exceeding small, it is manifest, why no sensible heat accompanies it.

However, though there is no proof, that a proportional quantity of heat does not always accompany every degree of light; yet on the other hand, it is manifest, that there is no necessity for the same degree of heat to be always attended with the same quantity of light; for many bodies will be very hot without shining at all.

Heat, therefore, is an effect produced by the rays of light, but may also be produced without them. But the sun's rays being the great instrument of the heat and warmth whereby all nature is invigorated, the consideration of light very naturally led the great sir Isaac Newton to enquire a little into so very-important an effect of it. As a means to obtain some idea how heat is propagated, he proposes the following experiment. Let two thermometers, each included under a glass, be removed from a cold room into one that is warmer; and let one of the glasses be exhausted of its air, the other not: then it will be seen, that the thermometers thus inclosed will soon feel the warmth of the place into which they are brought; and that from which the air has been exhausted, will be affected nearly as soon as the other. In like manner, if the ther-

thermometers be carried from a warm room into a cold one, they will ſoon be affected by the cold of the latter place; and that from which the air is withdrawn, will feel the change near as readily as the other. For greater ſatisfaction, he directs the experiment to be made in the dark, that the light of the place may not be ſuſpected to have any influence in the ſucceſs of the experiment. Now, as the thermometers cannot be affected without ſome agent to operate upon them, there is ſomething within the glaſſes, by which this effect is produced. The air is extracted out of one of them; it is not therefore the air that cauſes this appearance: nor can the heating of the thermometers be cauſed by particles of light latent in the air of the warm room; for if ſo great a quantity of ſuch particles were to ruſh on the thermometers, by being reflected from them, they would become viſible; for we have already ſhewn, that a leſs quantity of light, than what is ſufficient to produce ſenſible heat, is very viſible: and when the thermometers are affected, upon being removed into the colder place, it is ſtill more manifeſt, that they do not grow cold by any particles of light eſcaping from them, becauſe they could not but be ſeen. In ſhort, there is no room to avoid ſuppoſing, that the glaſſes with which the thermometers are co-

vered, do both contain in them ſome ſubſtance that will remain after the air is withdrawn, by the means of which the heat is communicated between the ſpace within the glaſſes and the air without; ſo that the ſpace within the glaſſes will receive warmth from the ambient air, when the glaſſes are brought into the warmer place; and when they are carried into the colder room, this ſubſtance within the glaſſes will propagate its heat to the air without; and by that communication of its heat, grow itſelf colder, loſing from itſelf ſo much heat as it imparts to the other.

By this experiment of ſir Iſaac Newton, we ſee, that it is not by the air chiefly, that hot bodies communicate their heat to cold ones near them; nor that hot bodies have their heat diminiſhed by the neighbourhood of thoſe which are colder. An experiment, which I ſhall now make, will farther conduce to ſhew how heat is propagated. If a ſmall wire be held in a flame, wherein it would ſpeedily grow hot; when a larger body of metal, on which the flame cannot act ſo ſtrongly, is contiguous to the wire, or only held very near it, in the ſame flame, the wire will not be affected ſo ſoon as when it is held in the flame alone: nay, I have held a very ſlender wire in a flame, under theſe circum-

ſtances,

ſtances, without being able to bring it to a red heat at all. We ſee, that the tallow in the wick of a lighted candle will not burn down to the very body of the candle; but that the body of the candle keeps this tallow within ſome diſtance too cool for it to take fire.

(Here the experiments.)

Theſe experiments, I think, evidently ſhew, that every hot body neceſſarily affects ſomething without itſelf; and when that ſubſtance without is indiſpoſed to be ſo affected, the body cannot grow hot under that operation, which would otherwiſe have heated it: ſo that, upon the whole, we cannot doubt, but that the diſpoſition of any body, which we term its heat, is owing to ſome ſubſtance every where preſent, which being in any place affected after ſome certain manner, will communicate heat to any body reſiding in that place, in proportion to the degree wherein the ſubſtance is ſo affected. What kind of ſubſtance this is; what the diſpoſition of it is, by which it heats bodies; and how bodies are affected when hot, is in the next place to be conſidered.

Heat dilates and enlarges the dimenſions of all bodies. This effect of heat has given riſe to the invention of the thermometer; which is nothing elſe than a veſſel ſo contrived as to meaſure, with great exactneſs, the degree of expanſion of

ſome fluid contained in it. All bodies, both fluid and ſolid, ſuffer this effect from heat; that, when hot or warm, they take up more room than when colder.

The only exceptions to this rule are ſuch bodies, which in ſome degrees of heat are fluid, but, by a ſufficient diminution of it, become rigid and brittle. The moſt known example of this is water freezing into ice. Water contracts itſelf more and more by cold, like other bodies, as long as it remains fluid; yet, as ſoon as it freezes and becomes ice, it expands itſelf again very remarkably. The like happens alſo to melted iron, which congeals into a brittle body; though this is not ſo in other metals, which, when cold, are ductile: but this is owing to the change of texture which they undergo, whereby they are rendered brittle. It is manifeſt in ice, from its being leſs tranſparent than water, that its pores are become larger.

(Here thermometers ſhewn; and the ſeveral rods extended by heating them; alſo the pin and hole.)

The reaſon of this ſo ſingular an appearance we ſhall enquire into hereafter.

From this general effect of heat in dilating all bodies, it muſt be concluded, that heat puts the the parts of all bodies into motion; for, without

2 ſome

ſome motion in the parts, the whole body could not be ſwelled. We ſhall find alſo, upon further examination, that the ſmall parts of matter are put and continued, by heat, in a vibratory motion. By this, they emit, when hot to a certain degree, particles which affect the eye with the ſenſation of light. The ſun ſeems only to be a great globe of matter heated ſo hot as to emit light and ſhine. Heated bodies alſo, by this vibratory agitation of their parts, emit fumes. The fumes which hot bodies emit, are ſuſpended from falling down again by the air; but the air contributes nothing to their emiſſion; on the contrary, it is an impediment. Bodies, when the preſſure of the air is removed, emit fumes with a leſs degree of heat than they will do in the open air; as water will boil with a leſs heat in vacuo, than when expoſed to the air: nay ſome bodies, when freed from the preſſure of the incumbent air, will ſend out fumes, which, in the open air, never are known to emit any.

Having here made mention of the light emitted by bodies when hot, I ſhall ſhew whence the the change of colour ariſes, which is ſeen in the emitted light, as the body increaſes in its heat. Almoſt all bodies, at firſt, emit red light, which by degrees alters, till with the moſt intenſe heat, the light becomes white.

Sir Isaac Newton has shewn, that the rays of light which affect the organ of sight with the colour of redness, are the least refrangible of any; the yellow light something more refrangible; the green still more; the blue more than the green; and the violet light most of all. Hence it appears, that the action between bodies and the red rays is the weakest; and in the rest the action is stronger, in proportion to the degree of refrangibility; and agreeably hereto, a less action of heat suffices for expelling the red rays than for the rest; and all the other rays are expelled, in order, as they are less refrangible. Whence the light first emitted by hot bodies is red; and with the increase of heat, it gradually changes, by the accession of rays of other colours, till being at length compounded of all colours, it becomes white. Where the heat is so strong as to throw out the blue and neighbouring rays in an over-great proportion, the light emitted is blueish.

Here, perhaps, it may not be amiss to obviate an objection, which this account of the emission of light from hot bodies may possibly suggest against what has been concluded in relation to the propagation of heat. It may be supposed, that the rays emitted by hot bodies, may not be confined within the limits of those

which

which affect our organ of sight. The rays of light, as they approach to the extremity of the most, and also of the least refrangible, grow of so obscure a colour, that they seem gradually to lose the power of affecting our sense. Now, perhaps, it may be asked, whether bodies, not hot enough to emit lucid rays, may not, however, throw out some less refrangible than any we can see, which, by falling on other bodies, may excite heat in them. But, notwithstanding this supposition, we can know, that no such means as this is the primary cause of the propagation of heat. This is certain, from the observation before laid down, that a hot body does not only communicate heat to a cold body near it, but likewise, that a cold body will diminish the heat of a hot one brought into contact, or within a small distance of it: for this diminution of the heat can no way be effected by the intervention of these rays; for, by the cold body's reflecting them back upon the hot one, its heat would rather be preserved than lessened, since we see the rays of light, after reflection, excite heat no less than when they issue directly from the lucid body.

But to return, what kind of motion the parts of bodies have by heat, will appear from the due consideration of light.

There

There is a mutual action between light and bodies; as light is emitted by hot bodies, so the rays of light, by falling on bodies, heat them, and are themselves refracted or reflected by the bodies. But the rays of light must heat bodies by acting on this substance, upon which their heat depends; consequently the reflection and refraction of light are caused by the same substance; for, as the action between light and bodies is mutual, without doubt, the effects on both are caused by a common agent acting between them. Now, several appearances in the reflection and refraction of light make it necessary, that some vibratory motion should be propagated by the light, through this substance, or medium; because it is found, that the light is disposed to be differently affected in different places, as it passes on, the same disposition returning successively at equal intervals. By these alternate dispositions of the light, I mean, those fits of easy transmission and reflection, into which, sir Isaac Newton has shewn that light is successively put, in its passage through transparent bodies.

But if this medium, or substance, of which we have been speaking, is put into such a vibratory motion by the rays of light; and, while it is thus moved, by its agitation heats the bodies on

on which the light falls; it is manifest, what kind of motion it puts the parts of bodies into, when it heats them; viz. the like vibratory motion.

In the last place, as elastic substances are the only ones through which this kind of vibratory motion can be propagated, we must conclude, that this medium, by which bodies are put into that disposition, wherein their heat consists, is elastic: and as our ear is so formed, that the vibratory motion of the air shall agitate the membrana tympani in that organ, in such manner as to excite in us the idea of sound; so the vibratory motion of this more subtile medium will so agitate our organs of feeling, as to give us the sensation of heat.

Sir Isaac Newton, in speaking of this medium, has thought fit to distinguish it by the name of æther, or the ætherial medium.

Now, as the rays of light heat bodies, by exciting a vibratory motion in this æther, and thereby communicating a vibratory motion to their parts; so other means of communicating such a motion to the parts of bodies, will produce heat.

A strong attrition, or collision of many bodies together, will cause a great heat. All metals, by hammering or filing, conceive heat: a small bar of iron, hammered briskly, may soon be brought

brought to a glowing heat: the iron, in the axle-tree of coach-wheels, if not well greaſed, whereby the briſk attrition is prevented, will heat ſo much as to ſet fire to the wooden axis: and, by ſtriking fire with a flint and ſteel, the heat is ſo great, that the ſparks which fall are no leſs than melted globes ſtruck off from thoſe ſubſtances.

Now, it is evident, that ſuch colliſion muſt put the parts impreſſed upon, of thoſe bodies, into a briſk motion: but ſince the vibratory motion of the ætherial medium will communicate ſuch a motion to the parts of bodies, and action and re-action is every where equal, a quick vibratory motion in the particles of bodies muſt be capable of exciting alſo in the medium a vibratory motion, and thereby propagating the ſame through the whole body.

Why all bodies are not heated by motion and attrition, depends upon circumſtances in their make, which are to be inquired into hereafter; but in the mean time, it may be obſerved, that thoſe bodies which are moſt heated by the rays of light, are alſo heated moſt eaſily by theſe other means.

We ſhall likewiſe ſee hereafter, that there are ſtill other means in nature of raiſing heat, without either the aſſiſtance of the rays of light, or a body already heated.

But

But now, upon the whole, what we know concerning heat amounts to this. The parts of solid bodies are not so fixed, and do not so unmoveably adhere to each other, as might at first be thought; but even the most rigid are attended with a disposition, or rather power, almost continually varying, whereby their parts are sometimes removed farther from each other, and sometimes less: and this power is so extended round the body, that if a body be brought near another, less under the influence of this power it shall increase this power in that body, and farther dilate it; but if the other body is more under the influence of this power than the first, the approach of the first shall diminish that influence, and cause that body to contract. When any body, by its contact or near approach, thus affects the sensible parts in us, if it causes them to dilate, it raises in us the sensation we call heat; if it causes the parts of our bodies to contract, we feel a sensation, which we call cold: lesser degrees of the first we call warmth; and small degrees of the other, coolness. These several terms relate to our sensation; but when the state of bodies, as they are more or less acted upon by this dilating and contracting power, is considered abstractedly from the sensations raised in us, one term is sufficient to express

it,

it, under the denomination only of different degrees of heat. When this heat is sufficiently great, bodies become luminous. Whence this light proceeds has been a question: some have supposed it to be only a pulse, propagated from the shining body to the eye, through an intervening medium, in the same manner as sound is propagated through the air, from the sounding body to the ear: but the circumstances accompanying the passage of light are inconsistent with this supposition. When the direct passage of sound to the ear is intercepted, it will take a compass round; a sound will come over a hill; but if any body not transparent is interposed between the lucid object and the eye, the sight of it is entirely lost. This, and some other properties attending light, leave no room for us to form any other idea of it, than as certain particles of matter propelled from the luminous body to the eye. But here another question arises, whether this light is emitted out of the body, or is a substance every where present, and is only protruded from the hot body, by that motion affecting the organ of sight. What has given rise to this latter supposition is this; that the rays of light are found to raise heat in all bodies upon which they fall: it has therefore been imagined, that they may be the immediate instrument

ment of heat, present in all places, operating to that end, even when they are not seen. But, as light is not always seen to issue from bodies, though considerably hot; and there are means of exciting heat, without any visible assistance from the rays of light; so no known properties of light qualify it to be the immediate instrument of heat, since it has been shewn, that the producing cause of heat must enable bodies to diminish, as well as increase, the heat of others. Hence it appears, that this supposed general presence of the matter of light in all parts of space, and the powers ascribed to it, are a mere hypothesis, not warranted by the appearances in nature.

On the other hand, that light may be lodged in bodies is evident. When the rays of light fall on any body, though a reflection ensues, by which the body becomes visible, yet scarce any body reflects back all the light incident upon it: most bodies retain the greater part which they receive within themselves. Hence all bodies exposed to the light of the day must have within a portion of the material of light, where, probably, it is no useless part of their composition, since it has been found, that those properties in light, whereby it is ordinarily reflected, and refracted, or renders bodies visible, are not the

only

only qualities it is possessed of. And if light be a requisite ingredient in the composition of bodies, no wonder, that by heat it is emitted from such as are taken from the deepest recesses of darkness, as well as from those which constantly communicate with the day. Even the subtle matter, whatever it be, in electrical experiments, contains and emits light: that it is not composed simply of rays of light is certain; for they widely differ in properties. The reflection of light in those experiments is accompanied with a sound, and even smell: this matter passes not through all transparent substances indifferently, like the rays of light; it does not pass through water as it does through glass; and through glass it passes without refraction. By this it appears, that it does not consist of mere rays of light; but that light is an ingredient in its composition, and occasionally struck out of it, accompanied with a degree of heat, productive, when the matter is copious, of very sensible effects.

As it has been shewn, that the dilatation of bodies from heat is effected by a vibratory agitation of their parts; from this it is, that heat is the great instrument, in chemistry, for resolving bodies into their principles; for, when this agitation is increased beyond a certain degree, the parts

parts of mixed bodies separate from each other, and the similar parts associating together, appear under a new form, from what they did in the compound.

But, before I proceed to consider more particularly the several principles, into which bodies are divided by the fire, it will be convenient to shew the various ways, in which heat is applied by the chemist to the bodies, whereon he operates: and this shall be the subject of our next meeting.

* To find the proportion between the quantities of light we receive from the sun and from the moon.

PROPOSITION I.

If two bodies are equally luminous, the quantity of light we receive from each is in the duplicate ratio of the sines of half their apparent diameters.

The quantity of light received from two equal bodies at different distances, is in the reciprocal duplicate proportion of the distance; and the sines of half the apparent diameters of the bo-

* The three following propositions were not, I presume, read in the course of the lectures; but as I find them in the doctor's manuscript, I have thought fit to print them.

dies are in the reciprocal proportion of their diſtances; therefore, the light received from two equal bodies, at different diſtances, is directly in the duplicate ratio of the ſines of half the apparent diameters.

Moreover from two bodies equally luminous at the ſame diſtance the light received is as the ſurfaces from which the light is emitted, that is in the duplicate ratio of the ſines of half their apparent diameters. Therefore if neither the diſtances nor the bodies are equal, yet ſtill the light received from each will be in the duplicate ratio of the ſine of half its apparent diameter.

PROPOSITION II.

The denſity of the ſun's light at the moon, is to its denſity, when emitted from the ſurface of the ſun in the duplicate ratio of the ſine of half the angle, under which the ſun is ſeen from the moon to the radius.

The light emitted from the ſurface of the ſun at the moon is diſperſed over the ſurface of a ſphere, whoſe centre is in the ſun, and its ſemidiameter the diſtance between the ſun and moon. The denſity therefore of the ſame quantity of light being reciprocally proportional to the ſurface over which it is ſpread; the denſity of the

ſun's

sun's light at the moon will be to its density at its exit from the sun's surface, as the surface of of the sun to the surface of the forementioned sphere; that is in the duplicate ratio of the semi-diameter of the sun to the distance of the moon and sun, or in the duplicate ratio of the sine of half the angle, under which the sun appears from the moon to the radius.

PROPOSITION III.

To find the proportion between the light we receive from the moon at the full, to the light we receive from the sun, upon supposition that the moon reflects all the light incident upon it.

By Prop. I. if the moon and sun were equally luminous the light received from the moon would be to that received from the sun in the duplicate ratio of the sine of half the apparent diameter of the moon to the sine of half the apparent diameter of the sun. But the density of the sun's light at the moon is to the density of the sun's light at the sun's surface, in the duplicate ratio of the sine of half the angle, under which the sun appears from the moon to the radius, (by Prop. II.). Therefore if the moon received the light of the sun upon all parts of the hemisphere obverted

toward the sun under the same degree of density, and reflected all the light incident upon it, and were at the same distance as the earth, the light reflected to us from the moon would be to the light received from the sun in the duplicate ratio of the sine of half the moon's apparent diameter to the radius. But at the full, the moon being somewhat further distant than the earth, the light received from thence is somewhat less.

But all parts of the moon's surface, by reason of its spherical figure, receive not the sun's light incident upon it under the same degree of density. The moon receives on its whole surface no more light than can fall on so much of the surface of the sphere, wherein the moon moves, as is included within the moon; that is about half as much, as if the sun's light fell on all parts of the moon with equal density; therefore, the light received from the moon will be but half what is above assigned, though the moon reflected all the sun's light incident upon it.

LECTURE III.

THE operations of chemiſtry, may, in general be divided into two ſpecies, analyſis and compoſition; by the firſt bodies are reſolved into their conſtituent parts or principles; by the other the productions of this analyſis are recompounded with one another, or with other bodies: indeed all mixture of bodies, where an artificial application of heat is requiſite to procure or aſſiſt their combination may be ranked under this ſynthetic branch of chemiſtry.

With reſpect to the analytical part, the effect of fire in general upon moſt compound bodies is to drive a part off from the reſt in vapour, while another part remains behind, and bears the force of the fire unmoved: ſome bodies, indeed, are wholly raiſed in vapour, and others remain entirely unmoved. This has occaſioned a general diviſion of ſubſtances into fixt and volatile; thoſe being volatile, which fly away in vapour; and thoſe fixt, which remain behind. Perhaps there are no ſubſtances to be found here on the earth, which will endure

above a certain degree of heat, before they are diſſipated; but this diviſion of bodies into fixt and volatile ſubſtances has relation to the force of fire uſually applied by chemiſts: theſe terms are merely relative; and as thoſe ſubſtances, which become volatile with one degree of heat, may remain fixt in a leſs, ſo it is uſual to compare ſubſtances together both in degree of volatility and of fixity; thoſe bodies being accounted moſt volatile, which fly off with the leaſt heat, and thoſe the moſt fixt, which indure the ſtrongeſt fire. We as often ſpeak of ſubſtances as more or leſs fixt, as we do under the notion of more or leſs volatile. Nor is it to be underſtood, that there is one eſtabliſhed degree of heat, which diſcriminates the ſubſtances, that are to be ranged among volatile ones, from thoſe which are to be ranged among the fixt: the ſame body may have both terms applied to it, as it ſhall be compared with different bodies; but it is moſt uſual to compare the effect of ſmall degrees of fire on bodies under the notion of volatility, and to uſe the other term of fixity, when the effects of ſtrong fires are conſidered.

If we have recourſe to what was ſaid in the preceding lecture concerning the operation of heat on bodies, we may form ſome judgment

of the properties required in bodies to render them volatile.

The action of heat is to communicate a vibratory motion to the particles of bodies, before those particles can become volatile, and fly off from the body, to which they are joined, they must suffer such a degree of agitation, as will separate them, and set them free from the body they adhere to. Therefore the stronger any particles adhere to the rest of the mass, the less volatile will they be. Thus we find, in chemical processes upon heterogeneous bodies, many substances to be exceeding volatile, when separated from the compound; which yet require a great force of fire to expel them thence.

Another condition necessary to render particles of matter volatile, is such a constitution, as disposes them to be easily agitated by heat. One condition, that may be conceived to render a body more easily put into motion, is the having a rare structure, or but a small quantity of matter in proportion to its magnitude. It is certainly not necessary, that all volatile particles should be smaller in bulk than others; for we shall see, that very fixt substances will unite themselves with volatile ones, so that the compound shall be volatile: and in this case, the volatile particles are larger than the fixt were;

for the fixt are become volatile by the accession of new matter. But here the great rarity of the added part may make the whole to be lighter, in proportion to its bulk, than the fixt particles alone were.

However the particles, whose specific gravity is least, do not for that reason only make the most volatile substances; but the former consideration must be joined with this, when we judge of the volatility of a body: thus oil, by the great tenacity and adhesion of its parts together, is much less volatile than water, though its specific gravity be less.

What the absolute minuteness of the particles of matter may contribute toward their volatility, would best be determined, if it could be known, whether the aethereal medium, which we proposed in the preceding lecture to be the immediate instrument of heat, acts only on the surface of these particles, or acts also on their internal parts. If it acts only on the surface, the minuteness alone of the particle may contribute towards its easy elevation, because the smaller a particle is, the more surface there will be to be acted upon in proportion to the magnitude of the particle. A globe, whose diameter is half the diameter of another globe, is but one eighth part of the bulk of this other, but has

one fourth part as much surface; therefore, the surface of the lesser globe is twice as great, in proportion to its bulk, as the surface of the greater. If the aetherial medium, as it pervades the particles, acts also with equal force on the internal parts, the absolute magnitude of a particle must contribute little toward its volatility.

But thus much is here observable, that this aetherial medium is so altered at the surfaces of bodies, that it there only acts on light in refracting and reflecting it; why may it not therefore act more forcibly on the particles of bodies at their surface, than on their inward parts?

However, we shall hereafter find some farther circumstance concurring to vary the volatility of bodies, viz. their abounding, more or less with an active principle found in some degree in all bodies, which the chemists have called sulphur. Perhaps, from hence must be deduced the principal cause of the diversity in the volatility of different substances.

But to proceed, as it is the design of chemistry to bring under examination all the parts, into which bodies are resolvable by the fire, the body examined is to be lodged in such a vessel, as may assist in collecting the ascending vapour.

There are two kinds of vapour, which arise from heated bodies; one sort condenses into a li-

liquor; the other under a dry form. Separating the liquid vapour is properly called diſtillation; raiſing the dry vapour is called ſublimation.

The moſt general inſtrument of diſtillation is the retort, where the aſcending vapour paſſes through the neck, and is received into another veſſel fitted on to it, and called from this office a receiver. Theſe veſſels are uſually made of glaſs, that being a material, in which the ſubject can be kept perfectly clean, and free from the leaſt taint. In caſes, where a greater heat is neceſſary, than glaſs can ſupport without melting; inſtead of the retort we make uſe of an earthen veſſel, uſually called a long-neck; this is formed of a ſhape ſomething different from the glaſs retort; becauſe, in ſome of the ſubſtances, which are diſtilled with theſe veſſels, the vapour riſes very ſluggiſhly, and will not aſcend far; therefore theſe veſſels are ſo ſhaped, as to give the vapour a more horizontal paſſage. Sometimes the neck of theſe veſſels is made crooked, and then the veſſel is called a crook-neck.

In caſes, where it is neceſſary to put to diſtillation a great quantity of materials, and where the vapour is ſo copious, as would require a receiver of immenſe bigneſs to contain it, a particular contrivance is made uſe of to condenſe the vapour in its paſſage. For this end the

va-

vapour is let paſs through a contorted pipe, or worm, lodged in a veſſel filled with cold water, by the coldneſs of which, what enters the worm in vapour, runs out condenſed into a ſtream of liquor. The veſſel here uſed to hold the matter to be diſtilled is too large to be made of glaſs; it is uſually made of copper, which being well tinned within is ſufficiently ſecured from giving any tinge to thoſe kind of ſubſtances for which this veſſel is made uſe of. This veſſel is commonly called a copper ſtill, and the pipe, through which the vapour paſſes, is fixed to a head, which lifts off from the body of the ſtill, for the convenience of putting the materials in and taking them out: this head is properly called the alembic. Theſe are the veſſels uſed by the diſtillers in drawing their ſpirits. In ſmall ſtills of this kind, a more compendious method is made uſe of for condenſing the vapour, which is by including the head itſelf in a veſſel of water.

There is alſo another method of performing the operations, for which theſe inſtruments are commonly uſed; which is by what is called the cold ſtill, becauſe here a much leſs heat is uſed. The material to be diſtilled is laid on a copper or iron plate, firſt covered over an inch thick with ſand or aſhes, or put into a leaden

pot

pot set upon such a plate. Over this is placed a conical head to receive the ascending vapour, which by a nose fixed in this head descends into a receiver. The fire must be kept very low, that the vapour may rise so slowly and so cool, as not much to heat the head, which receives it, that it may condense without any help, except, perhaps in some cases by laying a wet cloth upon the head of the still.

There are also smaller vessels, of a like structure with the copper body and alembic now described, made of glass, which are but little used by the practical chemists. However they are sometimes convenient, when we desire to separate very volatile substances from each other; for then a tall glass of this form is best fitted to give room for the most volatile substance to separate from what is less volatile, by rising higher: with a low glass it is not so easy to prevent their ascending together.

These glasses are also useful in collecting dry vapours, or in sublimation, the head or alembic being made without a beak, which is usually called a blind head. How the practical chemists supply the use of this vessel, shall be shewn, when we come to operate on the particular substances, upon which they usually perform these sublimations.

But

But these subliming vessels are only to be used, when the vapours easily ascend. When they require a strong fire, and are forced up with difficulty, it is usual to put the matter into a globular vessel with a long stem, called a matrass, or bolt-head: here the vapour ascending, fixes on the upper part of the globe.

When a large quantity of materials is to be sublimed, an earthen jar covered at top with a moveable iron plate is sometimes made use of.

When what rises from a body, while heated, is to be neglected, and the operator's intention is only to regard the change wrought by the fire, on what remains fixt in it, such subjects are sometimes put into iron vessels, as pots, ladles or the like, often into earthen ones. Of this kind are crucibles made of an earth, that will well endure the fire. For some particular purposes vessels are made of the ashes of burnt bones, or of horns of animals burnt, which latter are preferred. These are particularly necessary for the refining of silver, as we shall see hereafter. They are called cupels, or tests. The method of making them is to moisten the ashes, till they will just stick together, when pressed in the fingers; and then to stamp them hard in a brass mould. Sometimes these ashes are stamp-

pot ſet upon ſuch a plate. Over this is placed a conical head to receive the aſcending vapour, which by a noſe fixed in this head deſcends into a receiver. The fire muſt be kept very low, that the vapour may riſe ſo ſlowly and ſo cool, as not much to heat the head, which receives it, that it may condenſe without any help, except, perhaps in ſome caſes by laying a wet cloth upon the head of the ſtill.

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ed into an iron ring, and put along with the ring in the fire.

The operations, which materials undergo in all these vessels, may be reduced under the two general names of melting and calcining.

These are the vessels of most general use in the analytical part of chemistry. In the other part, which concerns the mixing bodies, for such an artificial application of heat as may be required to effect their combination and union, but few instruments are in general requisite: except the common instruments of pots and kettles, or the like, the glass-body and bolt-head above described are for the most part sufficient.

When the stem of a bolt-head is closed, by inverting a less glass of the same kind into it; if the heat applied raise any vapour from the included materials, at the height of the upper bolt-head, it will cool and fall down again; by this means, if the glasses, before they are joined, be made warm, any liquor may be boiled without wasting in vapour.

Two bolt-heads thus joined compose, what the chemists call circulating vessels. We find in books other vessels also of a more complex form described under this name; but they have no advantage over these here mentioned.

If the ſtem of the bolt-head be continued alſo downward into the body of the glaſs, and left open by a very ſmall orifice only, the bolt-head is then called an infernal glaſs: but this is a contrivance uſeful only for ſome particular purpoſes, to be explained hereafter.

The next thing now required is to explain the method, by which the junctures of veſſels are to be cloſed; for when a vapour is paſſing, from a retort for inſtance, into the receiver, unleſs the juncture be cloſed, where they are fitted together, a part of the vapour will eſcape. This cloſing up the junctures of veſſels is called luting, and the materials, by which it is performed, lutes.

Lutes are of various ſorts. For inſtance wheat-flour and water ſpread upon a fillet of linen or paper makes a good lute to hold in watry vapours raiſed with a ſmall heat.

Horſe-dung, mixt with twice its quantity of fine clay or loam makes a good luting for moſt purpoſes. This is the luting chiefly uſed by the practical chemiſts.

Windſor loam, wherewith the bricks are beſt laid in furnaces, that are deſigned to endure a ſtrong heat, makes alone a very good luting, and is therefore moſt convenient, for thoſe who exerciſe chemiſtry for entertainment or ſpecu-

lation;

lation; but those, who follow it as a trade, prefer that which is least expensive.

Whiting, flour, and house-sand in equal proportion made into a paste with strong brine is also a commodious luting.

In authors we meet with the description of several other lutes, but these are sufficient.

Sometimes glasses are shut up by heating their stem red-hot, and the opening either melted up, or pinched close: this is called sealing hermetically.

In chemical operations the luting most generally used is loam, as before mentioned. If this be applied to the juncture of the glasses so closely, and so long before the operation is entered upon, that it shall become perfectly dry, and would close the juncture so absolutely, as to hinder any manner of air or vapour from finding its way out; when the glasses grow in any great degree hot, they must necessarily be broke by the expansion of the air alone imprisoned within them. If the luting be applied immediately before the operation, the ascending vapour will keep it continually moist, and thereby will escape too freely through it. It is best to lute the vessels one day, and make the fire the next: by this means, the luting will not be so very close,

close, but that it will give a little passage to the included air upon its first expansion, and will dry, as the glasses grow hot, timely enough to hold in as much of the vapour, as is consistent with the safety of the vessels. The luting above described, with whiting and flour, hardens more easily, and therefore need not be applied any length of time before the operation is begun.

Many of the chemical glasses come from the glass-house with long, and sometimes irregular necks, that it is often necessary for the chemical operator to cut a part off, before he lutes them together. This is usually performed, by heating them, where they are to be cut, and touching them with a little moisture, which causes them to crack, and the superfluous part to fall off. The glasses may be heated either by a hot iron ring of the size of the glass to be cut; or by binding round them a thread dipped in oil of turpentine, brimstone or the like combustible substance, and setting the thread on fire. With the iron ring the glass most commonly breaks off without wetting. Small pipes of glass are best broke by notching them with a file, and then breaking them off with the fingers.

The next thing to be considered is the method of applying the fire in chemical operations.

tions. In these operations it is a necessary circumstance, that the fire be carried on regularly, either the same degree of heat continued, or equally raised without wavering. For this end, when the fire is not to be of the most violent kind, the vessel, containing the substance to be operated upon, is not usually exposed to the naked fire, but is rather heated by the intermediation of some body between. Water is a commodious medium, when no greater heat is required than what water, when boiling, conceives, because the heat of boiling water is never to be augmented. The different force of the fire under it may cause it to boil away faster or slower; but when it once boils out freely, its heat will never after increase.

Water thus applied chemists call balnæum Mariæ. Sometimes they direct the distilling vessel to be placed in the vapour only of the water. This is called distilling in a vapourous bath, and is a less heat than the other.

Horse-dung also affords a very steady heat, and is of long duration. This is a very commodious heat to promote putrefaction. With this heat also the vapour of vinegar is raised, for corroding of lead, to make ceruse or white lead, as will be particularly explained hereafter.

When theſe heats are not ſufficient, ſand is made uſe of. The practical chemiſts generally make uſe of ſand for every heat, from the leaſt to the greateſt, ſand is capable of. For this end a pot of caſt iron is ſet in a furnace of brick, ſo built that the fire may play well round the pot, and heat it as equally as may be. It is uſual to carry the flame and ſmoke from this fire under an iron plate covered with ſand, before it paſſes up the chimney; by which means they have a ſmaller heat of ſand to be uſed at the ſame time with the pot, without an additional expence of fuel.

Filings of iron would give yet a greater heat than ſand.

The advantage of interpoſing all theſe kinds of ſubſtances is, that their heat is not ſo fluctuating, as that of an open fire; for when the fire is quite put out, their heat will continue a conſiderable time; and when the fire riſes, their heat does not increaſe at the ſame inſtant with it, but follows it gradually.

However, when a greater degree of heat is neceſſary, than what ſuch ſubſtances will give, an immediate fire muſt be made uſe of. This is of two ſorts. The mildeſt of theſe is an open fire, ſuch as may play on the bottom, and about the ſides of the veſſel in the man-

ner, as the iron pot before mentioned is heated.

When glaſs veſſels are to be expoſed to this fire, it is neceſſary to cover them over with an earthy coat. This may be made of potter's clay, mixed with ſand till it loſes its unctuouſneſs, and will no longer ſtick to the fingers; or ſand may be mixt with the forementioned luting of clay and horſe-dung. Windſor loam and Stourbridge clay, with which the pots of the glaſs-houſe furnaces are made, are ſtill better ſorts of coating, uſed alone without any mixture.

The reverberatory fire, where the fire being made under the veſſel, the paſſage for the flame and ſmoke is directly over it, gives ſtill a greater heat than the open fire now mentioned; for here the flame encompaſſes the whole veſſel, beating on the very top, as well as on the bottom and ſides. In this fire, earthen veſſels are only to be uſed.

There is alſo another kind of reverberatory heat, when the fire is made on one ſide of the veſſel containing the matter to be wrought on, and the flame draws over the veſſel to its exit through the chimney. In this, the greateſt heat is applied to the upper ſurface of the ſubject.

There is alſo another method of accommodating the greateſt heat to the top of the ſubject, which is by placing the ſubject under an earthen cover, and heaping the fuel over it. This cover is uſually called a muffle; and the furnace wherein it is uſed, muſt have an opening to correſpond with the mouth of the muffle, by which the ſubject to be wrought on may be taken in and out. In a furnace of this kind, called from its uſe an eſſay-furnace, are made the eſſays of wrought plate at Goldſmiths-hall.

When the fire is required to be the ſtrongeſt of all, a wind-furnace is made uſe of; which is a furnace ſo built, that there may be a very ſtrong draught of air to blow the fire, and give it the greateſt ſtrength poſſible. A blaſt alſo, with large bellows will procure a very ſtrong heat; but theſe bellows muſt be double, after the manner of thoſe uſed by the ſmiths, that the blaſt may be continual; though no heat can be raiſed by this means, to exceed what may be obtained in a good wind-furnace. The principal uſe of bellows is, when a great heat is required to be excited very quick.

The flame of a lamp blown to a point by a ſmall pipe gives a very ſtrong heat, and is often applied to melt ſmall pieces of metal or the

like. Workmen often uſe it in ſoldering ſmall work.

In relation to the kinds of fuel, it is to be obſerved in general, that charcoal gives the ſtrongeſt heat, this fuel having no humidity like wood or coals. Coals give the moſt intenſe heat, after their humidity is evaporated, and they ceaſe to flame.

Oil alſo and ſpirits are made uſe of burning in a lamp, when a ſmall quantity of materials is to be wrought on, and the degrees of heat theſe lamps will afford, are ſufficient. This is, in particular, a commodious method of continuing a conſtant heat for a great length of time; for it is eaſy to have a lamp, that will keep burning twelve hours or more.

There is alſo another method of continuing a heat in one conſtant degree without much attendance, by the furnace uſually called an athanor, or tower-furnace. This furnace is a tall cavity raiſed on a grate, which has an aſh-hole underneath: this cavity is called the tower of the furnace. In the ſide of this tower at a proper height above the grate is a paſſage for the heat to paſs out of the tower under an iron plate covered with ſand. There is ſometimes a ſlide over this paſſage, whereby it may be widened

dened or ſtraitened, and the degree of heat varied by that means. Now when the tower is filled up with coals, if it be well cloſed at top, no more of the coals will burn, than what lye between the grate and the paſſage before mentioned for the heat; becauſe here, and no higher, will be a current of air to blow the fire: all the reſt of the fuel above is only a ſupply to what ſhall be burnt to aſhes, and fall away through the grate; ſo that the height of the tower adds nothing to the ſtrength of the heat, but the higher it is, the leſs frequently will the fuel require to be ſupplied. In this furnace therefore a conſtant heat both night and day may be continued for any length of time with very little attendance.

The fuel in this furnace muſt be charcoal or ſome other ſuch-like fuel, that will burn away to pure aſhes. Sea-coal, by caking into cinders, will ſoon ſtop up the grate and put the fire out.

The method invented by Vigani of erecting furnaces, is very convenient for thoſe, who have not a fixt laboratory. His furnaces are compoſed of bricks ground to a pretty true ſquare, and made all of the ſame breadth, and of the ſame thickneſs. The bricks being ground, they will lie cloſe enough to confine the heat

without being fastened together by any cement.

Three or four rows of bricks are first to be set edgewise, for a grate, or to make a greater heat a second order placed in like manner across these, and where the greatest heat is required, a third or a fourth. Over these, the furnace is to be formed differently according to the purpose, for which it is designed. By this method a furnace may be fitted for any chemical operation whatever, even to the melting metallic ores, which are operations, that require the greatest heats of any.

The best fuel for these furnaces is charcoal: Scotch coal also burns in them very well.

In furnaces, where strong fires are used, it is of great consequence to choose a proper earth for the bricks, wherewith the furnaces are built. There are two qualities in earths, that dispose them to bear the fire, to be considered distinctly: one is, not easily to be melted, the other not to be disposed to crack in heating or cooling. Earths more easily melt by being charged with metallic particles: the earths that burn red abound in irony particles, and are therefore more apt to melt than those earths, that burn white. The earths, that burn into a hard brick,

are

are most apt to crack by the fire, which is an effect common to all brittle substances: glass is the most subject to it of any thing. The cause of this effect is the dilatation, which I observed, in the last lecture to be the effect of heat upon all bodies; for in these hard and brittle bodies, if they heat in different parts unequally, or if in cooling, a blast of cold air, or any other accident, too hastily cools one part; the body not being of a yielding substance, the contracted part separates from the dilated, and the body breaks.

In the glass-houses they are principally solicitous to find an earth, that will not melt with the violence and long continuance of those fires. A clay dug up near Stourbridge, in Worcestershire, thence usually called Stourbridge clay, is found the fittest for this purpose, with it the pots are made, in which the glass is melted, and the inside of the furnaces themselves used to be built: but lately a stone has been found near Newcastle, which at less expence answers the same purpose. Their fires being kept on continually for a great length of time they are less subject to be incommoded by the breaking of the earth; though, in their pots, they often suffer by that accident.

In other furnaces, where the fire is often varied and extinguiſhed, a looſe ſandy kind of brick is moſt commodious; for the parts of this brick hanging looſely together eaſily yield to that alteration, which the change of heat makes in them. Thoſe called Windſor bricks are the beſt of any in this country; and ſhould be laid in Windſor loam, not in mortar.

When it is neceſſary to make any veſſel of the harder clay, that muſt undergo frequent changes of heating and cooling; to ſecure this earth the better from breaking, with the freſh clay is ſometimes mixt a good portion of what has already been burnt, broken into pretty groſs pieces. By this inequality in the texture the compound becomes ſomething more durable. In this manner the Heſſian crucibles are made; and alſo the pots in which they make braſs in England.

In great part of chemical operations divers materials are mixt together, and as they are uſually proportioned by weight, I ſhall conclude this lecture with a brief explanation of the ſeveral weights in uſe.

In England, we make uſe of two different pounds: the one is called the pound avoirdupoiſe,

poiſe, and the other the pound troy. The pound avoirdupoiſe is ſomething larger than the other. It is that, by which large quantities of moſt goods are bought and ſold. In this weight, what is called the hundred weight is not a juſt hundred pounds, but contains a hundred and twelve of theſe pounds: and twenty ſuch hundred weights are called a ton. This pound is divided into ſixteen ounces, and the ounce into ſixteen drams. In this weight more minute diviſions are not in uſe.

The pound troy is divided, by the ſilverſmiths, for weighing of ſilver, into twelve ounces, each ounce into twenty pennyweights, and the pennyweight into twenty-four grains. At the mint they ſubdivide the grain into twenty parts called mites. Gold is alſo weighed at the mint by this pound, but otherwiſe divided; the pound being here divided into twenty-four parts called carats, and each carat into four parts called grains: ſo that a grain of gold is equal to ſixty grains of ſilver.

The carat by which jewels are weighed, contains only four ſilver grains.

The phyſicians alſo preſcribe by the pound troy, but divide it ſtill otherwiſe. They have twelve

twelve ounces in the pound, but divide the ounce into eight drams, the dram into three scruples, and the scruple into twenty grains, whereby the grain becomes the same as in the division of the silver weights.

Though the extempore prescriptions of physicians are always adapted to the troy weight, and the officinal compositions are described in the generality of pharmacopœias by the same divisions of the pound; yet it has been a custom pretty general among our apothecaries to mix the ingredients of those compositions by the avoirdupoise weight; though the ounce in this weight bears a different proportion to the pound, than in the troy weight. But, in the present Pharmacopœia, this error is particularly guarded against.

Though the pound in the avoirdupoise weight is heavier than in troy weight, the ounce in the former weight is less than in the latter; so that ten troy ounces nearly equal eleven avoirdupoise; and seventeen pounds troy is very little short of fourteen pounds avoirdupoise.

The essayers, who examine very small quantities of metals, use still other weights. They take a small weight, which they call their pound,

pound, and divide this pound, as the troy pound is usually divided. Their pound for silver essays is about eighteen grains, and for gold essays six grains. The reason, that the silver pound is treble of the gold pound, is because in essaying of gold they mix silver with it in that proportion. The only convenience of this is to find names for the very minute weights, they must make use of, and to save the trouble of computation in their essays.

They have another artifice of more consequence in order to their weighing with exactness, which is to set their scales under a glass, which they call a lantern, whereby they keep them from being tossed about by the air.

Their scales are in general made so tender as to turn, with the hundredth, or even with the two hundredth part of a grain, sometimes with less. If they turn with the three-hundredth part of a grain, they will distinguish in a silver essay to a single grain. Though the essayers are not accustomed to report their essays of silver nearer than to a half-pennyweight, nor the essays of gold nearer than to one quarter of a gold grain.

It is also convenient in essaying metallic ores to be provided with a small weight to be called

called a ton, and divided in the ſame manner as the common ton. Though for this purpoſe the common troy weights are of themſelves not inconvenient; for if the ounce be conſidered as a ton, the pennyweights will repreſent hundreds: but for the diviſions of the hundred, either computation, or an expreſs ſet of ſmall weights muſt be uſed.

LEC-

LECTURE IV.

THE ſeveral ſubſtances, into which bodies are diviſible by the fire, differ greatly from one another. However there are ſome general characters, by which they may be reduced under a few heads. Chemiſts have reduced them to five, three volatile, water, or phlegm, ſpirits and oils, and two fixt, ſalts and earths. Theſe are commonly called the chemical principles. By water is meant a fluid without taſte, ſmell, or any other ſenſible quality to diſtinguiſh it from common water. By ſpirits are underſtood all fluids, which mix with water, and are endued with other properties than water itſelf. Oils are fluids, which will not mix with water; and theſe are alſo inflammable, contrary to the nature of water, which extinguiſhes fire. Theſe are the three diviſions, under which chemiſts range the fluids, that are ſeparable from mixt bodies. The other two heads of ſalts and earths comprehend the ſolid parts yielded by the mixt. A ſalt is whatever diſſolves in water, and unites itſelf ſo with it, as to make with the water one body, and to paſs through

through the closest strainer without being severed from that water.

The method of straining used by the chemists is most commonly with paper after this manner. They fold the paper so, that it may fit the cavity of a funnel, and pour the liquor into it; and the liquor, as it ouzes through the paper, runs down the neck of the funnel. Straining in the language of the chemists is most usually called filtring, and the strainer a filtre. Most of these substances called salts, since they are not volatile, and fly away as soon as heated, melt and flow in the fire like metals. The other solid substance separated from mixt bodies, is that, which remains, after all the foregoing are separated, and is a dead earth without any sensible properties, but those which are necessary to the constitution of mere matter. It will not dissolve in water as salts do, nor will it melt in the fire. If it be ever so much agitated and mixt with water, it would soon subside from it again, being specifically heavier: in the fire it remains unaltered. This substance seems to be the basis of bodies, and to give them their shape and texture.

Water is the principle, which seems to be the most simple, next after this earth. It is surprizing to see, how great a quantity of it is to

be

be drawn from bodies, which appear perfectly hard and dry. There are ſcarce any bodies, beſides ſtones and metals, that do not yield a conſiderable quantity upon diſtillation. The particles, which compoſe it, join themſelves to the other parts of bodies, and unite ſo with them, as to ſhew no ſigns of humidity; yet, when ſeparated, forthwith aſſume their native form. This fluid, by ſo freely uniting itſelf with other ſubſtances, becomes the chief inſtrument, next after heat, of natural operations: for the active parts of matter, by ſwimming in this fluid, move themſelves, and follow without impediment the influence of thoſe powers, by which they operate. Without this fluid to give eaſy motion to the particles of matter, the powers of nature could have very little effect. Thus we ſee, that water conveys to all plants their nouriſhment; and the food of animals is rendered fluid by the digeſtion of the ſtomach, before it can be carried farther into the body, and be made uſe of for its nouriſhment.

This principle of water is poſſeſſed of a more extended power, by which its parts adhere together, than what is to be found in the earth before mentioned. For wherever water is laid on any thing, which it will not wet, as upon what is oiled, it forms itſelf into ſpherical drops

by the mutual attraction of its parts; and, when mixed with the forementioned earth, it causes the parts of that to adhere firmer together than before. But notwithstanding this power of cohesion between the parts, wherewith water is endued, a small degree of heat serves to make the parts adhere so weakly, as to keep it fluid; though we find a certain degree of cold will permit it to form itself into a very hard mass in freezing.

This effect of the absence of heat upon water deserves well to be considered. Water contracts in its dimensions by cold, as all other bodies do; until such times as it freezes. Then it swells again.

The cause of this so remarkable an effect we have promised particularly to inquire into.

The academy erected at Florence for the cultivation of natural philosophy, which was the first of those societies in Europe, have long ago made very many judicious experiments upon this matter.*

There are certain mixtures, whereby so very intense a degree of cold may be procured, as will speedily freeze water.

Ice in powder, or snow mixt with common

* Saggi d'Esperienze di Acad. del Cimento, Firenze, 1667.

salt,

salt, nitre, and some other salts, will soon freeze a small vessel of water set into such a mixture. It is to be observed, that the ice or snow always melts, before it produces this effect. At the instant of its melting it gives the most intense cold. After this its cold gradually diminishes by the warmth of the circumambient air. The cause of this freezing power I conceive to be, as follows. Any of these ingredients, which mixt with the snow or ice produce this cold, are such as being mixt with water, are a great impediment to its freezing. This is a known effect of common salt, the most usual ingredient, with which freezing mixtures are made. These ingredients do not hinder the freezing of water by keeping it warmer. But as the freezing of water is owing to a disposition peculiar to that fluid, these substances hinder it, by changing that disposition. Any of these materials being mixt with ice already formed, soon reduce it to the same liquid state, they would have kept it in, had they been mixt with the water before its freezing. And the ice is here dissolved without losing any thing of its coldness. Now the coldness of ice, if it can be communicated to water without diminution, will freeze it, for the degree of cold in the ice is that, which retains it in that form, and prevents it from returning to

water, therefore that degree of cold, communicated to other water, muſt turn that alſo into ice. Now a heap of ſnow or ice in powder is a collection of particles of ice, with interſtices between filled with a warmer medium. Therefore, if any veſſel of water be ſet into ſuch a heap of ſnow or ice, the cold communicated to the water will be no greater, than what reſults from the coldneſs of the ice or ſnow compounded with the warmer condition of the interſtices. But when the ſnow or ice is liquified by the means before mentioned, then the veſſel is ſurrounded by one uniform body of cold equal to that of a ſolid body of ice. Therefore in this caſe the water in the veſſel will freeze, in the other caſe not.

The ingredients mentioned may ſomething haſten this effect, in that being put into water, they increaſe its coldneſs, while they are diſſolving in it, as we ſhall ſee hereafter. Though common ſalt will aſſiſt but little on this account. Nay vinous ſpirits, will not only quicken the freezing power of theſe mixtures by haſtening the liquidation of the ice, as the forementioned gentlemen obſerved; but will alone produce the ſame effect, as ſucceſsfully as the ſalts themſelves: yet theſe ſpirits in mixing with water give an additional warmth to it.

The

The gentlemen of the forementioned academy plunged a globular glaſs with a very ſlender ſtem into ſuch a freezing mixture, as we have now deſcribed, the glaſs being filled with water till it roſe to ſome height in the ſtem. At the firſt immerſion of the glaſs they obſerved the water to riſe, but ſoon to ſubſide again, till it ſunk ſenſibly below its firſt height. The riſe of the water on the firſt immerſion of the glaſs they ſoon perceived to be owing to this cauſe, that the glaſs by being in immediate contact with the freezing mixture was firſt affected by the cold, and by contracting diminiſhed its cavity; but when the water began alſo to be affected, it ſunk again and continued to ſubſide; till at length it would riſe again, at firſt ſlowly, but in a little time very faſt. As ſoon as this motion was over, the glaſs being lifted out of the freezing mixture, the water was found to be frozen. By repeating the experiment often, and frequently raiſing the glaſs out of the mixture, they ſometimes had the good fortune to take it out, at the inſtant it was going to freeze, ſo that it would ſometimes freeze before their eyes. In this caſe upon lifting up the glaſs, the water would appear as clear and tranſparent as ever; but on a ſudden would become opake, and at the ſame time riſe up in the ſtem of the glaſs:

and then the water was frozen. This opacity of ice above water explains the whole myſtery of the dilatation of the water upon freezing. Sir Iſaac Newton has clearly proved, that the tranſparency of bodies is owing to the ſmallneſs of their pores; and that nothing more is neceſſary to render a pellucid body impervious to the light, than to render the pores of it large enough. Thus, when the moſt tranſparent glaſs is beaten to powder, the powder is opake, or impervious to the light. Why the largeneſs of the pores of a body produces this effect, ſir Iſaac Newton ſhews at length, viz. by the light's ſuffering ſucceſſive reflections at the ſurfaces of each particles, as it paſſes through the pores, till it is wholly loſt.

By the great opacity therefore of ice in reſpect of water, we know that the particles of water in freezing unite into little maſſes, and form larger particles, which neceſſarily occaſion great pores between them. And by this means they compoſe a body, which takes up more room than before, while they ranged themſelves in a more uniform manner. That the particles of water ſhould take ſuch a difference of arrangement upon cold, as to enlarge the bulk of its body, muſt be owing to their particular make and conſtitution; perhaps to the configuration

guration of them; for oils will grow thick and opake by cold without ſwelling thus; nor do they become hard and brittle, as water does. But this property of dilating upon changing from a fluid ſtate to a ſolid, is not peculiar to water alone: it is common to all bodies that melt into a fluid, and are brittle when cold.

(Here freeze a water-thermometer with ſnow or ice and ſalt; and with the ſame and ſpirit of wine.)

In the next place, to conſider ſalts and ſpirits; after having given the eſſential characteriſtics, whereby ſalts are to be diſtinguiſhed from other ſubſtances, it will be proper to explain the grand diviſion of them into acid and alkali, which has made much noiſe among the natural philoſophers. All the principles in philoſophy of ſome men have been confined to theſe two. This diviſion of ſalts does in reality deſerve our greateſt attention. But as all ſpirits, except the inflammable vinous ſpirits, ſeem to be only a diſſolution of ſome ſalt in water; in what I am going to ſay upon acid alkali, I ſhall ſpeak of ſalts and ſpirits promiſcuouſly.

An acid is properly that, which taſtes ſour, when applied to the tongue, whether it be a dry powder, or a liquor, that is, whether it be ſalt or ſpirit: for it is to be obſerved, that of

dry bodies salts only are the proper subjects of taste, for earths being undissolvable in water, and unactive substances, will not dissolve in the saliva nor act upon the nerves of the tongue, otherwise, than as by drying up the humidity, wherewith the tongue is moistened, they may create a perception, which in the common phrase of speech may be comprehended under the general name of that species of sensation, to which this organ is appropriated. The alkalis are such salts and spirits, as, when mixt with acids, raise a conflict and effervescence, and in the end deprive them of their acidity. Some acids will ferment with each other. Oil of vitriol for instance ferments with the weaker acid of spirit of salt: but here the mixture still remains acid.

(Here the experiments of acids fermenting with alkalis.)

What this fermentation is, and to what cause its visible effects are owing, will be inquired hereafter.

Sir Isaac Newton seems to think, that the acid principle is the great agent in nature, which sets at work the other parts of matter. There is a paper written by him particularly upon acids.

It

It was communicated first to Dr. Pitcairne, and by his means came into the hands of others. It was at length printed in the second volume of the Lexicon Technicum of Dr. Harris. Sir Isaac there says, I call acid, what attracts strongly, and is strongly attracted. He apprehends acid particles united to earth to be the composition of all salts. Even that the alkalis, which are usually treated as the opposites and antagonists of the other, he supposes to be only earth joined with an acid strongly attractive. But his opinion in these particulars we shall more distinctly inquire into, and explain in the course of these lectures, as we prepare the particular substances to which these opinions relate.

But to proceed, besides these marks I have given to distinguish between acids and alkalis, there are other methods made use of to discover them. Sometimes an acid or alkaline quality lies hid in a subject so as not to manifest itself very distinctly to the senses, by the foremen-tioned direct trials; yet will produce such effects, as more manifest acids and alkalis are known to do. One of these effects is the change, they occasion in the colours of many bodies. Syrup of violets, is commonly made use of in these trials. Acids turn its blue colour

lour into red, alkalis change it to green. But Mr. Boyle recommends above all the tincture of lignum nephriticum.

If cold water be poured upon a few ſhavings of this wood, it ſoon acquires a tincture, which looked upon appears blue, but ſeen through appears red. This blue tint is taken off by an exceeding ſmall quantity of acid, even when the tincture is made very deep. For this reaſon Mr. Boyle recommends it as the moſt ſubtle criterion of acidity. Alkalis heighten the blue tincture.

(Here the experiments with ſyr. viol. and tinct. lign. nephrit.)

No other ſpirits, beſides thoſe which are acid or alkali, have been much conſidered in chemiſtry; except only the inflammable vinous ſpirits. Mr. Boyle has made ſome mention of other ſpirits, and calls them neutral.

Neutral ſalts are commonly known; ſuch is common ſea-ſalt, we uſe at the table; ſuch alſo is ſalt-petre, the largeſt ingredient in gunpowder.

Inflammability is a property, which belongs to no ſpirit, except the vinous ſpirit; but all oils are poſſeſſed of it. This ſo remarkable a property of theſe fluids, while water on the con-

trary is a potent extinguiſher of fire, deſerves particular conſideration.

It has been obſerved before, that all bodies, when heated to a certain degree, emit light and ſhine; water can never receive ſo great a degree of heat. The heat it has, when boiling, is the greateſt, the moſt intenſe fire can give it, and with this heat it flies away in vapour. This property of water, of being incapable of any great heat, is that, which enables it to extinguiſh fire.

It has been obſerved in a former lecture, that heat diffuſes itſelf from the hot body, and decays gradually. That it never ſtops ſhort, and is interrupted at once; inſomuch that the near approach of a cold body to a hot one neceſſarily diminiſhes the heat. For this reaſon, when cold water is thrown upon a piece of hot metal, or a burning coal, the heat of the body is neceſſarily leſſened, till the water is by degrees heated and thrown off in vapour. But ſince water can receive but a ſmall degree of heat; if, as faſt as the hot body diſſipates the water thrown upon it, freſh water be ſupplied, the body muſt at laſt be reduced to the heat of boiling water only. But with this heat no bodies known, except the phoſphorus from urine, will burn. Thus fire muſt be extinguiſhed.

Oils

Oils are capable of receiving a greater degree of heat, than water is; insomuch that the steam, which rises from them, will emit light and shine; and when oil has acquired this heat, it will continue it, and consume away in a shining smoke or vapour; that is, the oil will burn.

It may be asked, why oil, when heated to this degree, should continue thus hot without diminution, till it is consumed, though no other fire be near it; whereas hot water, when removed from the fire grows gradually cool again. This is common to oil with all burning bodies, and they all require the presence of the air for this purpose. Any burning body in a close place, where all access of fresh air is excluded, soon is extinguished and grows cool.

There is another particular in the heat of burning bodies, which is likewise owing to the air. These bodies, like all others, grow gradually hot by the influence of the heat applied to them, till the instant in which they take fire. At that moment their heat increases many fold on a sudden. As they will not burn without the assistance of the air, so they never receive this sudden increase of their heat, if the air be absent, but will grow gradually hotter and hotter, as other bodies do,

till they come to the greatest heat, they are capable of.

Burning bodies do not all require the same degree of heat to set them on fire. Brimstone will take fire, and flame with less heat, than is required to fire oil, spirit of wine with less heat than brimstone, and the phosphorus made from urine, with much less heat than spirit of wine. And sometimes the bodies, that take fire with the least heat, are the hottest, when on fire. The flame of spirit of wine is hotter than the flame of oil; and the flame of the phosphorus from urine much hotter than either.

In short, bodies take fire by an action between them and the air, and a certain degree of heat is required in every body (though not in all the same) to excite this action. This action continues all the time the body burns. As soon as it ceases, or is diminished beyond a proper degree, the burning is extinguished. By setting a body on fire in a close vessel this action is discovered to have a very remarkable effect upon the air itself; for it is found to destroy the elasticity of part of it. If by an air-pump the air about the burning body is gradually rarified; or though the air remain equally condensed, as the body in burning charges the air with fumes, which mixt with it causes less and less pure air to

to be in contact with the burning body: in both these cases the burning soon ceases.

But in the open air, the air near the burning body being rarified by its heat becomes lighter than the rest of the air, and therefore must ascend, while its place is supplied by fresh air, which being rarified, in its turn also ascends. By this means a constant current of fresh air flows by the hot body.

There is but one other body known, which is possest of this property of the air, and that is nitre. This substance, we shall hereafter see, will make bodies burn, upon which the air cannot easily be brought to have any such effect; and being an ingredient in gun-powder, causes that to take fire without the assistance of the air.

But what kind of action this is, whereby the air keeps bodies on fire, we shall see more distinctly hereafter.

As this action of the air is the only means found here upon the earth of continuing heat without diminution; it is not improbable, that the sun is a body actually on fire, kept burning and in a flame by an air, which encompasses it. Perhaps the vapours arising in this flame, after circulating a time in the sun's atmosphere fall down, and become combustible again If so, the sun will continue for ever burning without being

being consumed. The changes seen in the surface of the sun agree very well with its being such a burning body; nor is its density too great, being not above one-fourth of the density of our earth.

Thus I have endeavoured to give some account of the five kinds of substances, into which bodies are divisible by the fire. These are considered by the modern chemists, as so many principles, on which they build their reasonings.

Paracelsus and his train are more concise: they enumerate but three principles, salt, sulphur, and mercury; by the first meaning whatever is fixt, by the second whatever burns, and by the third all that is volatile; which Paracelsus illustrates after this crude manner, in wood on fire, what burns in it is sulphur, the smoke is the mercury, and the ashes the salt.*

But in regard to the five substances, which have been here enumerated, the great question, which occurs is, how far they deserve the name of principles. If by principles are meant the original forms of the particles of matter, by whose union in various proportions all compound bodies are produced, while themselves are neither alterable nor divisible by any natural

* Quod ardet, sulphur est; quod effumat, est mercurius; qui cinis relinquitur, sal est. Vol. i. p. 34. col. 1.

powers;

powers; these, we have here called principles, certainly deserve not that appellation; for they are themselves compound substances, and their constituent parts separable by chemical operations, as we shall see in the course of these lectures. But as the first operation of the fire in analyzing bodies divides them into some, or all of these substances; they are the first step in chemistry towards disclosing the nature of each compound: and what additional progress can be made in the knowledge of natural bodies must be deduced from examining and farther decompounding these.

Besides the five substances here mentioned, there is another produced from bodies, though not so much taken notice of by chemists. This is an aerial vapour, which, when purged from the heterogenous substances that rise with it, seems to be true permanent air.

I shall only add here, that the chemists have been many of them very confused injudicious writers, confounding the use of their terms without end. And thence some names in common use are not conformable to the definitions, I have given above. For instance, oil of vitriol, and oil of tartar per deliquium, are by no means properly to be called oils, for both will mix with water, nor is either of them inflammable.

They

They are in nothing like oil, but in a little ropineſs, which appears in them, as they are poured out of a bottle.

After this explanation of the general effects of the chemical analyſis, at our next meeting, I ſhall proceed to conſider compoſition.

LECTURE V.

AFTER explaining the general effects of chemical analysis, and the principles of natural bodies, that discovers; chemical composition is next to be considered.

All mixtures of different bodies, fluid or solid, where their parts are mutually united, come under the present head. But the most eminent of these mixtures is, when a fluid is endued with a power of insinuating itself between the parts of a solid body, and uniting with them. In this action indeed the parts of the solid body are separated from each other, and therefore the body is not improperly said to be dissolved; but as the effect of this is to unite the parts of the body with those of the fluid, the action comes properly under the head of chemical composition. When the fluid dissolves the whole body, and receives all its parts intire within itself the operation is merely composition; but often the effect of such dissolution is more complex; and while one part of the body is united with the fluid, some other either flies off

in

in vapour, or ſubſides: here there is a combination both of analyſis and compoſition.

Every fluid, which has a power to diſſolve other bodies, is called a menſtruum. The operation of the menſtruum is owing to ſome power, whereby its particles attract and adhere to the parts of the body, it diſſolves; the particles of the menſtruum muſt likewiſe be in a diſpoſition, that they can eaſily move toward the body to be diſſolved; and fluidity beſt fits them for this end. Pure water is a menſtruum to all ſalts. And all the reſt of the menſtruums are no other than water impregnated with ſome active particles.

Sir Iſaac Newton is of opinion, that wherever any diſſolution is made, there an acid is preſent, if not manifeſt to ſenſe, yet latent; in which he only expreſſes his ſentiment, that acid particles are the active principles, that attract other bodies, and are attracted by them. Thus he apprehends every kind of ſalt to be only an acid joined to ſome other ſubſtance. He chuſes to call theſe active principles acid, becauſe he ſuppoſes, that whenever they ſhould be united with water alone, they will exhibit that taſte. Though neither ſea-ſalt, nor nitre has any acid taſte, yet ſpirits very ſtrongly acid are to be ex-

pelled from them, after which the remains will be a mere earth.

The greatest part of menstruums are saline; spirit of wine indeed partakes of the nature of an oil, and its dissolving power chiefly consists in associating with itself, the unctuous parts of vegetables. Thus we shall see it dissolve resines, or the inspissated oils of vegetables, and extract them from the compound, in which they are lodged.

We have already observed, that the menstruum must have its parts moveable, that they may come readily in contact with the body, they are to act upon; and that this requires fluidity. In a fluid state, the active principles, while swimming in a liquor, easily move. By this means they readily approach the body, they are to work upon; and being in contact with it penetrate the body; the active particles of the menstruum insinuating themselves between the particles of the body, and carrying along with them part of the fluid, wherein they float, they disunite those particles: that is, they separate them so far asunder, till they can no longer act on each other, so as to cause a coherence. Then the particle of the body in dissolution is invested by the dissolving particles of the menstruum,

and carried away with them into the fluid. Thus the body, though heavier than the fluid menstruum, is suspended in it, so as to compose one fluid body with it.

It is here to be noted, that these active particles of the menstruum do not attract one another, but the other particles of the fluid, wherein they swim. Whence in the fluid they are dispersed equally throughout it, and, when they have dissolved a body, they in like manner diffuse the parts of that body uniformly through the menstruum.

When menstruums dissolve bodies, a visible motion is frequently, though not always seen in them, and bubbles filled with air rise in great plenty. This motion is called by the name of fermentation, a word first applied to that intestine motion raised in paste by the means of leven in order to break the mucilage of the grain in the preparing of bread; but now by chemists is used generally for every kind of visible effervescence, such as is seen in mixing any fluid either with another fluid, or with a solid body.

Heat promotes the acting of menstruums. A menstruum, when heated, sooner dissolves a body, than when cold, and while hot, will retain more of the dissolved body, than it can hold afterwards, a part subsiding, as the men-

ſtruum cools. Thus water will keep more ſalt or ſugar diſſolved, while hot, than it will retain, when grown cold again. Nay if care be taken to impregnate the hot menſtruum with the body to a ſufficient degree, the parts of the diſſolved body, when the menſtruum is become cold, will unite together again, and ſeparate from the menſtruum.

It is not difficult to conceive, upon what principle heat promotes the action of menſtruums. Heat dilates all bodies, and we alſo know, that by ſo doing, it diminiſhes the coheſion of their parts; for it not only quite ſeparates the parts of many bodies, when it ariſes to a ſufficient height, but univerſally in every degree renders bodies ſofter; thus fluids by heat become more liquid, and the moſt rigid ſolids diminiſh in firmneſs, till they become quite flexible, or even fluid. But as the action of menſtruums is to diſunite the parts of bodies, we need ſeek no farther to know, what aſſiſtance heat gives to this action, than that it leſſens the coheſion of the bodies to be diſſolved.

As the action of menſtruums is promoted by heat, ſo the temperature of the menſtruum is for the moſt part changed during the time of its acting, from what it was before. Moſt frequently the menſtruum grows hot. In ſome

caſes

cases it grows cold. The like also is often observed in mixing fluids with each other.

To form some idea of two such opposite effects, let us consider, that as the action of heat is to expand bodies, and keep their parts at a distance; so the action of a menstruum is to draw the parts of the body towards its own parts; that is, while it operates to cause a contraction of the whole: and this being an action contrary to the action of heat, it is hence very conceivable, how cold is produced. To discover whence heat arises in these cases, it must be known, and shall hereafter at large be shewn, that there is one substance in all bodies; by the copiousness of which in inflammable bodies, they are indued with the power of burning. We often shall call it the inflammable substance or principle: it is also usually called sulphur. Now sir Isaac Newton shews, that light, and consequently heat, operates immediately upon this part in bodies. We shall hereafter see, that in all visible fermentations a part of this is carried away in the frothy bubbles, that break through the liquor. It may also go off invisibly; for when it goes off in the visible appearance of bubbles, another substance accompanies it. Such an agitation of the sulphur, as to expel part of it out of the body, must excite heat;

this being the ſubſtance immediately operated on, and put into motion, when a body is heated. In this caſe therefore we are to conſider two cauſes operating together; the forementioned contraction productive of cold, and this expulſion of ſulphur, whereby heat is occaſioned. When this latter operation prevails, the mixture grows hot.

Saltpetre and ſal ammoniac (ſalts we ſhall hereafter take under particular conſideration) mixt with water produce cold, mixt with ſtrong ſpirit of vitriol produce a great heat, but the acid ſpirit may be ſo much diluted with water, that cold ſhall reſult from the mixture, though not in ſo great a degree as from mixing thoſe ſalts with water alone. And in this caſe while a thermometer plunged in the mixture is affected with cold, another ſuſpended over it ſhall receive heat from the aſcending vapour, an evident proof that in this caſe both the cauſes before mentioned operate.

It is here to be noted, that as bodies are made up of particles, which are themſelves compoſed of other particles; ſo theſe menſtruums diſſolve only the groſs body, but not the particles which compoſe it. Their parts adhere together by a force not to be overcome by theſe powers.

Action

Action and reaction in all bodies are equal; therefore, when I here ſpeak of menſtruums diſſolving bodies, I would not be underſtood, as if the power of diſſolving aſcribed to one of the bodies was a property of a diſtinct kind from the diſpoſition to be diſſolved attributed to the other. The diſſolution is mutual, for the parts of both are removed farther from each other than before.

When a fluid acts on, and divides the parts of a ſolid, it is uſual to ſay, the ſolid body is diſſolved, and that the fluid is the diſſolver. But indeed the effect in ſtrictneſs is, that both ſubſtances become united, and as the fluid, by inſinuating itſelf into the ſolid body, has ſeparated its parts, and diſperſed them throughout itſelf, ſo the fluid has its parts in ſome meaſure ſeparated by the particles of the other body coming into it, and the reſult is a compoſition of the two ſubſtances into one.

Two things farther are to be remarked concerning menſtruums. One is, that after they have diſſolved any body, if another body, whereon they act more vigorouſly, be put into them, they quit the firſt body in order to lay hold of the ſecond; ſo that the firſt body ſhall fall down, if it be heavier than the menſtruum, which is the moſt common caſe, and is called precipi-

cipitation. If the first body dissolved be lighter than the menstruum, it will swim on the top of it. This not being a very common case has no particular name; but is in effect the same with the other.

Another particular to be here observed is, that when a menstruum by the assistance of heat has been charged with a greater portion of the substance dissolved, than it will retain, when cold, the redundancy does not always simply subside, but frequently gathers together in grains of some specific shape. And this manner of the dissolved body's separating from the menstruum is called crystallization; wherein to render the grains deposited large and in their most perfect form, some management is necessary. If the liquor is too strongly impregnated, the grains concrete together, and their true figure not easily perceivable. The most certain method is to dissolve the materials, which are principally salts, when pure water is the menstruum, in a large quantity of the liquid, and then to evaporate to a due degree.

The rule generally given for determining the proper degree of evaporation is to proceed with a gentle heat, till a skin, or in the more usual language of chemists, a pellicle appears upon the surface of the water. By this is known

known in moſt ſalts, when the hot liquor is ſo far impregnated with the ſalt, that a part will ſeparate from it, when cold. In nitre this pellicle ſcarce appears. Thoſe, who perform this operation upon nitre in large quantities, judge of the evaporation by the weight of the liquor; for the ſalt being a more ponderous body than water, the water, as it is farther charged with ſalt, becomes more weighty. But we may alſo judge when the liquor is diſpoſed to ſhoot, by taking a little up in a ſpoon, and waiting till it is cold, and if the liquor be ſufficiently charged with nitre, the ſalt will begin to appear in ſmall threads. Sea-ſalt and borax, if the water be ſufficiently evaporated, will ſhoot, while the water is hot.

This cryſtallization of ſalts is an operation, which greatly merits conſideration. It promiſes no inconſiderable light into the nature of thoſe powers, by which the ſmall parts of matter act on each other.

If the leaſt quantity of water be poured upon a parcel of ſalt, it will ſoon be diſperſed through it; but the ſalt being a heavier body than water, the upper part of the wet ſalt will have more water among it than the bottom, the ſalt by its weight thruſting up the water.

If there were no action between the water and the salt, the water would be all kept upwards, and the salt lie at the bottom as compact together, as it did, before the water was put to it. But by the action, there is, between the parts of the salt and of the water, the water will take up some of the salt, and sustain it against the power of its gravity. If more water be poured on, more of the salt will be taken up, till at length with a due quantity of water all the salt will be dispersed through the water; insomuch that the lowest part of the water will scarce, if at all, be more impregnated than the very top. But for this effect there requires a certain quantity of water in proportion to the salt. And in different salts this proportion is very different.

With the heat which water will have in a moderate temper of our air, common salt requires less than three times its own quantity of water to keep it dissolved; nitre requires somewhat more than common salt; green vitriol scarce twice its own weight; but alum requires near seven times its weight of water; and borax twice as much.

As water, by a great heat, can be much more strongly impregnated with any of these

ſalts, than when cold; ſo, when the water cools again, the overplus by its gravity will ſubſide.

But the particles of the ſalt, when not kept ſeparate by the water, have a power, whereby they approach and adhere to each other. Therefore, if the water be ſo far only evaporated, that this ſubſidence of the ſalt may be performed leiſurely, the particles of ſalt will act ſo on each other as to unite in cluſters, and form diſtinct bodies of a regular ſhape.

The colder the place is, in which the liquor is ſet, the cryſtalline bodies, into which the ſubſiding ſalt forms itſelf, will be the larger.

By the particles of the ſalt thus meeting together in regular ſhapes, it muſt be concluded, that before they began to meet, they were diſperſed through the water at equal diſtances from each other. And this is a natural conſequence of the action between them and the water; for each particle acting equally on the water, one particle will encompaſs itſelf with as great a quantity of water, as the other. The moſt difficult enquiry in this caſe is, what cauſes the particular figure, into which each ſalt ſhoots. This muſt of neceſſity ariſe in general from this

cauſe,

cauſe, that the particles of the ſalts are of particular figures; and that theſe ſalts on their different ſides have different powers of acting; for by this means theſe particles will meet on ſome of their ſides only, but not on others, and ſo form the particular figures, into which we find them to ſhoot. It appears very ſurprizing, that the particles of matter ſhould have ſuch different properties on their different ſides; but ſir Iſaac Newton has evidently demonſtrated this of the rays of light, ſo that the ſame thing may with leſs difficulty be admitted in other caſes alſo, where there appears any proof of it. Whether this can be occaſioned only by the figure or ſhape of the particle, will be beſt known, when we ſhall have gained a more diſtinct inſight into the cauſe productive of this action between the parts of matter.

All that has been ſaid of ſalts equally obtains in metals, which, when diſſolved in their proper menſtruums, are diſpoſed to ſhoot out of them in ſome diſtinct form, after the ſame manner as ſalts do from water, and are then become a genuine ſalt.

A

COURSE of CHEMISTRY.

PART II.

On animal and vegetable Subſtances.

LECTURE VI.

BEING now to enter upon the particular proceſſes of chemiſtry, it is proper to begin with the moſt ſimple.

The ſubjects therefore, I intend here to treat of, are to be incloſed in a ſuitable veſſel, and expoſed to the gradual action of ſimple heat only. The veſſel, in which theſe ſubjects are incloſed, is placed in an open fire; that, before the operation is over, they may receive a great degree of heat.

The firſt ſubject, we ſhall conſider, is animal ſubſtances.

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The animal ſubſtance moſt wrought upon by the practical chemiſts is hartſhorn. They generally diſtil it in an iron pot, with a head fitted to it, to receive the vapours, and convey them into the receiver. It is alſo uſual for them to place a glaſs veſſel between the head of the ſtill and receiver, to give the vapour (or in the language of chemiſts, the fumes) more room to expand in; and being carried by this means farther from the fire, they alſo condenſe the ſooner. This veſſel they call an adapter. When very large quantities are diſtilled at once, they place another adapter, made of tin, between the glaſs adapter and the head of the pot. For a ſmall quantity of horns a coated retort, with or without an adapter, will ſuffice.

There is no other preparation uſed to fit this ſubject for diſtillation, but only to cut the horns ſmall enough to be put into the veſſel, wherein they are to be diſtilled. Nor is any thing mixt with them. The fire muſt begin ſlow at firſt, and be raiſed gradually, leſt the vapour riſing too impetuouſly, ſhould burſt the receiver.

When the diſtillation is finiſhed, that is, when with the greateſt degree of fire no more fume or vapour will aſcend; we find in the receiver three different ſubſtances: a fluid, which will mix

mix with water, therefore a ſpirit; another fluid, which will not mix with water, and will burn, that is an oil; alſo a dry ſubſtance diſſolvible in water, therefore a ſalt. There remains behind a black coal, ſtill retaining the ſhape of the horns. This coal, preſſed ever ſo long in a cloſe veſſel with the moſt intenſe fire, will neither loſe its blackneſs, nor its ſhape. But the blackneſs will ſoon be deſtroyed by a free admiſſion of the air to it, as will be ſhewn in a following lecture. We do not proſecute our operations now ſo far, neither on this, nor on the other ſubjects of the preſent lecture; becauſe we here intend only to ſhew the effects of ſimple heat, without the concurrence of any foreign aſſiſtance.

The ſpirit and ſalt are alkalis. Accordingly they turn the ſyrup of violets green. They give a diſagreeable colour to all red ſyrups alſo; and therefore, when they are uſed in medical preſcriptions, care ſhould be taken not to add any ſuch ſyrups, where this ſpirit is an ingredient.

This ſpirit and ſalt are the ſame, from whatever animal ſubſtance they are diſtilled; whether from harts-horns, vipers, or any other; alſo all the animal juices, as blood, urine, &c. afford the ſame. Theſe ſpirits and ſalts may

ſeem to differ a little, when firſt diſtilled; becauſe from ſome ſubjects they come more impregnated with oil, than from others; but in proportion as they are purified by the method, we ſhall deſcribe and perform at our next meeting, they gradually diſcover a more perfect reſemblance.

The principles hitherto treated of are found in every animal ſubſtance, whether ſolid or fluid; but there are ſome other productions peculiar to milk and urine, which deſerve our notice.

Milk in boiling emits a watry vapour, neither of an acid nor alkaline quality, till ſuch times, as what remains grows very thick, and acquires a great ſweetneſs. Whence this ſweetneſs takes its riſe will be ſhewn hereafter.

If milk ſtands any time, it ſeparates ſpontaneouſly into two parts, one of which is watry, and the other of a thicker conſiſtence: they both in a little time acquire an acidity. But the acidity of the thicker part is owing altogether to ſome of the watry part remaining ſtill with it: for if this watry part is well beat out, it becomes that oily ſubſtance butter. The watry part therefore is that only, which turns ſour or acid.

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The watry vapour, which arises from milk, will also by time grow sourish; for which reason the use of milk in distilled waters, directed in the writings of physicians, is with us wholly discontinued.

As milk is a fluid, that has for some time circulated in the blood vessels of an animal; so it begins to partake of the nature of the other animal juices: for though by standing it becomes acid, which happens not to any other animal juice; yet after fresh milk has been freed by boiling or a gentle distillation from its watry part; if it be then pressed with a stronger fire, an alkaline spirit will arise from it; and also an oil resembling the oil that comes from other animal substances.

Milk therefore appears to be reduced by the powers of digestion into a kind of middle nature between animal and vegetable substances; for as animal substances yield upon distillation the forementioned alkaline spirit and salt; so the greatest part of vegetables afford acid principles, as we shall see presently.

Hence it is, that milk is so very useful in hectical fevers; for milk approaching already so near to the animal nature, is easily converted into nourishment, and at the same time, by its having put off, as it were, but half its acid

quality, it is ſuited to cool the feveriſh heat, under which theſe patients labour.

In the next place, from urine is extracted that ſurprizing ſubſtance called from its perpetual ſhining in the dark phoſphorus, and this ſubſtance alſo contains an acidity.

If urine be diſtilled, while freſh, it ſends forth at firſt a watry vapour of the ſmell peculiar to urine. Afterwards with a ſtrong fire it yields the ſame ſpirit, ſalt and oil, as other animal ſubſtances, But, if the urine be putrid, the volatile alkaline ſpirit ariſes from it with the firſt heat. The reaſon of this change in the urine by putrefaction, we ſhall diſcuſs, when we come to take into conſideration that grand operation in the œconomy of nature.

The phoſphorus is obtained by diſtillation from urine putrified, by the force of a very vehement and long continued fire. The operation from the firſt invention of it has been kept, as a ſecret, till very lately in the Memoirs of the Academy of Sciences at Paris the proceſs is deſcribed at large, which the deſcribers aſſure us ſucceeded with them to their wiſh. The late Mr. Godfrey, with whom this ſecret remained, till the forementioned publication of it, informs us, that, if a quantity of the fæces alvinæ be digeſted along with the urine, a much larger

quantity of phoſphorus will be obtained, than from urine alone: alſo that the phoſphorus cannot be obtained from any ſubſtance, but what has undergone digeſtion in an animal body.

The phoſphorus melts, while under water, with a ſmall heat, and by that means may be formed into any ſhape. If taken out of the water in the night, or in a dark room, it ſhines vividly, and a very ſmall degree of heat ſets it on fire. But it will not even ſhine, if covered from the air. While it ſhines in the air, it waſtes in fume; but in water, or in ſpirit of wine, it is preſerved without diminution. No degree of heat will fire it under water, but if it be laid, when on fire, upon water, the fierceneſs of its flame will keep it up from ſinking; ſo that it will continue burning upon it, notwithſtanding it is twice the weight of water. After the flame of the phoſphorus is extinguiſhed, the remains ſhew manifeſt ſigns of acidity; the like are found, when a piece of the phoſphorus has been left open to the air to fume away. The fume condenſes into a very acid liquor. If, a piece of phoſphorus being ſet on fire, a large glaſs be whelmed over it, white flowers will ſettle round the glaſs, which are very acid, and expoſed to the air will attract a great quantity of humidity.

This ſubſtance is of no uſe in medicine. However it cannot but engage the attention of all, who have any philoſophical curioſity, by its ſurprizing properties.

(Here the experiments with the phoſphorus.)

Thus we have found in two animal ſubſtances, the milk and urine, an acid part, which is not to be found in any other, except perhaps in an exceeding minute quantity. To diſcover whence the acid, here found, is to be derived, we muſt proceed to the other ſubjects of this lecture, which are vegetables.

Some of theſe produce upon diſtillation the ſame principles, as are afforded by animal ſubſtances. Of this kind are muſtard-ſeed, horſe-radiſh, ſcurvy-graſs, and all the plants, that have a ſharp pungent ſmell and taſte; alſo ſome others, as ſponge and opium.

The analyſis of theſe plants, is but a late diſcovery in chemiſtry. Mr. Boyle is the firſt, who mentions it.

Any of theſe vegetable ſubſtances diſtilled in the ſame manner, as deſcribed before, after ſending out a fetid water, yield a volatile alkaline ſpirit and ſalt, together with a black fetid oil; leaving behind a black coal retaining ſtill the ſhape of the vegetable, and not to be burnt to aſhes without a free acceſs of the air.

But

But the greatest part of plants exhibit productions of another kind.

Besides a water, that first comes over, we find here a spirit, without any salt, and also a fetid oil so ponderous, as to sink in the spirit. The spirit here produced is an acid one.

There remains behind a black coal, which always continues the same, how long soever it be pressed by the fire in a close vessel. And here the parts of the vegetable still hang together, as in the other subjects.

Charcoal is only this coal made from wood by a compendious manner of distillation. The wood is piled up endwise round a kind of funnel formed with sticks laid across each other, and then is covered close over with earth, with only small vents, that when the wood is set on fire, which is done by throwing some kindled coals into the forementioned funnel, it may burn as slowly as possible, till all the volatile parts are expelled, and the wood is reduced to this coal. Then the fire is quite extinguished by closing up the vents.

In the open air this coal, once set on fire, soon burns to ashes, which, contrary to the ashes of both the former subjects, contain a salt, as will be shewn hereafter.

The farther examination of the coal remaining in all our present ſubjects muſt be poſtponed, till we come to conſider the effects of actual burning. But firſt we muſt examine a little farther the ſeveral ſubſtances, that have riſen from our ſubjects. As theſe are expelled from a ſubject, wherein they all adhered united together, ſo now they are not yet perfectly ſeparated; but each ſubſtance is left impure by a ſmall mixture with the others.

The farther purification of theſe we ſhall refer to the next lecture.

But here it is farther requiſite to take notice of one other ſubſtance, that ariſes from all the ſubjects of this lecture in diſtillation; which is an aerial vapour, that requires a particular artifice to collect it; in the method of diſtillation above deſcribed it is neceſſary, that the luting of the veſſels may be ſo applied, as to permit this vapour to eſcape; otherwiſe the receivers will be blown off, or burſt.

This vapour may be collected by the means of a retort having a long neck ſo bent, that it may open under a glaſs, inverted into water, the glaſs itſelf being alſo full of water. Then as ſoon as the retort grows warm, the air included within it will expand, and paſſing through the

pipe

pipe will riſe up, and place itſelf in the top of the inverted glaſs; and when the vapour iſſues from the ſubject diſtilling, it will follow the ſame courſe, and expel out of the glaſs as much water as is requiſite to make room for itſelf. After the diſtillation is over, this glaſs will have received all the aerial vapour produced from the ſubject, and alſo ſo much of the air contained originally in the retort, as has been expelled out of it by its expanſion. What this is may be diſcovered by expoſing the retort empty to the ſame heat, and will never amount to four-fifths of the whole air of the retort by the greateſt heat, that can be uſed. And thus may be known the quantity of aerial vapour, that is produced from any ſubject.

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LECTURE VII.

IN my laſt lecture I began to deſcribe the effects of ſimple heat on animal and vegetable ſubſtances; that heat will divide and ſeparate them into different parts. But as theſe do not at firſt come from the ſubject abſolutely diſentangled from each other, I ſhall now ſhew, how, by the the farther application of heat only, a more perfect ſeparation may be made.

To begin with the ſpirit, which in all theſe ſubjects is of a deep colour. This is owing to a ſmall portion of oil ſtill remaining in it. When this is ſeparated, the ſpirit will be tranſparent and colourleſs like water.

The ſalt alſo found in any of theſe proceſſes is foul with oil; and is tinged by it of a brown colour; when pure, it is perfectly white. I ſhall now therefore ſhew, how theſe ſpirits and ſalts are to be purified.

This may be accompliſhed only by diſtilling them over again with a gentle heat; for thus the oil will either be left behind, or ſwim upon the ſpirit diſentangled from it. One operation will not complete the work; perhaps all the oil can

can never be perfectly ſeparated by this means, but by repeated diſtillations it may be ſo far diminiſhed as not to be perceivable.

In theſe rectifications the heat of ſand is commonly uſed, an open fire not being eaſy to regulate for ſo ſmall a heat, as is here required.

The ſpirit and ſalt of hartſhorn are excellent medicines; theſe therefore ſhould be purified with much care. They may be mixt together, and diſtilled either in a glaſs body, or a retort, with the gentleſt heat poſſible. The rectified ſpirit will flow into the receiver, and ſo much of the ſalt, as the ſpirit will not imbibe, ſettles in a dry form in the head of the body, or on the upper part of the receiver, when a retort is uſed. Some ſalt is commonly waſhed down, and lies under the ſpirit undiſſolved.

Since a large quantity of oil comes from the hartſhorn along with the ſpirit; this muſt be ſeparated from the ſpirit, before that is ſet to rectify: otherwiſe by ſwimming uppermoſt it will prevent the ſpirit and ſalt from riſing.

The ſpirit and oil are ſeparated by pouring them both together into a common funnel, firſt ſtopping the bottom of it with the finger. The oil will ſoon riſe and ſwim upon the top of the ſpirit. Then the finger being removed the ſpirit

will

will firſt run out; and by timely replacing the finger, the oil muſt be prevented from following.

This is the general method for ſeparating oil and watry liquors. If the materials are coſtly, a funnel of another ſhape is to be uſed. The body of this funnel is of a globular figure, with a ſmall opening only at the top, which after the liquors are poured in, is to be ſtopt with the thumb or a cork. This opening being cloſed nothing will run out, though the bottom be unſtopt. But when the liquors are ſeparated, by opening the cloſure at top the undermoſt liquor may be let out; and, when that is all gone, the other prevented from following by cloſing the upper orifice again.

When the ſpirit of the preſent proceſs is mixt but with a ſmall quantity of oil, it is beſt to uſe the ſeparating funnel now deſcribed, which will preſerve the ſpirit from evaporating, while the oil is riſing. When there is a large quantity of oil, it will ſoon cover over the ſurface of the ſpirit, that no waſte by evaporation will happen in the common funnel.

In both funnels the ſeparation will be quickened by having the funnel a little warm, and the mild heat of warm water is the fitteſt to warm the funnel with. But the warming of the

the funnel is most necessary, when the oil is costly. In this case, the liquors being put into the separating funnel above described, it is very convenient to set the funnel in warm water, till the oil is risen.

(Here exemplify the separation of oil and water by both funnels.)

But to return to our process, the spirit and salt of the hartshorn require more than one rectification, as has been said, to render them pure. By repeated operations, the spirit will become as clear as rock-water, and the salt perfectly white. However the oil adheres so tenaciously, that they are scarce to be totally freed. And though you rectify the spirit, till it appears ever so clear, or the salt, till it is as white as possible, yet in time they will contract a yellow hue, a sure token, that they are still charged with oil, which at first was so divided and spread through the salt and spirit, as to be invisible, but at length gathers together and appears.

These spirits and salts are much more agreeable to the stomach, when wholly free from their yellowness. Therefore, when they have changed colour, they ought to be rectified again, to fit them for use. This is too little practised, though these medicines would hereby

be greatly improved: when the oil is got together in ſuch a body as to be viſible, it will then alſo become ſenſible to the ſtomach, and often cauſes patients, whoſe ſtomachs are weak, to complain upon taking theſe medicines.

It required a ſtrong fire to ſeparate this ſalt firſt from the ſubject, but now it is once ſeparated, it is ſo exceeding volatile, that it muſt be kept in a very cloſe vial, or its moſt ſubtile parts will fly away into the air.

This great volatility of the ſalt gives the ſpirit an advantage in medical preſcriptions; for ſhould the ſalt be mixed with any powder, or even bolus, it would ſoon fly away, and leave the medicine deſtitute of any virtue to be expected from the ſalt: whereas, when the ſpirit is added to a draught, or the like liquid preſcription, the ſpirit is eaſily confined by cloſe ſtopping the vial, wherein the medicine is contained. It is true indeed, that the ſalt may with the ſame advantage be preſerved by diſſolving it in a liquor; but the ſpirit, being already a fluid, will more readily unite with the liquor, than the dry ſalt.

Every time this ſpirit is rectified, it becomes more and more impregnated with ſalt, part of the water being being left behind every time

with

with the oil. At length it will be ſo much charged with ſalt, that it will ſhoot, and ſometimes even coagulate in the cold.

(Here ſhew ſome ſpirit and ſalt of hartſhorn completely refined.)

When this ſpirit riſes very pure; after the ſpirit will follow a water not diſcoloured with the oil, but ſcarce to be diſtinguiſhed from common water.

Alſo from the ſpirit upon every rectification a quantity of dry ſalt will ſeparate. Whence we learn, that the ſpirit is only water impregnated with this ſalt: accordingly, if this ſalt be diſſolved in water and diſtilled, it produces the ſame ſpirit.

Thus we ſee, that this alkaline ſpirit is water impregnated with a particular ſubſtance, to which it owes its alkaline quality.

What has been ſaid of the ſpirit and ſalt of hartſhorn, may be equally applied to the ſpirit and ſalt of thoſe plants, which produce the ſame with animal ſubſtances.

If the acid ſpirit produced from other plants be poured on chalk or coral, it boils up with it, and being diſtilled from it, comes over a watry fluid free from its acidity. That, which made it acid, it has left behind in the chalk or coral.

(*Here shew this fermentation.*)

It is remarkable, how inconsiderable a portion of matter contributes towards this acidity: for the weight of the liquor, by what it has left behind in the chalk, is scarce sensibly diminished. But this now left in the chalk or coral is alone the acid principle; all the rest of the liquor is no more than a fluid, wherein it swims. Why chalk or coral imbibes the acid from the fluid, it swam in, is not necessary here to inquire. It answers the present purpose, that we have a material capable of extracting this acid from the fluid. Mr. Boyle, who is the first, that put these acid spirits to this examination, observes, that, when the acid spirit is distilled alone with a very gentle heat, what rises at first will have little acidity; but be almost the same, with what is produced by the help of chalk or coral, which last was the medium he used. Herein this acid spirit differs from the alkaline spirit of the preceding subjects: for the first, that rises from that spirit, is the strongest; but here it is the weakest.

Though this spirit may be thus deprived of its acidity; yet it still retains properties, that distinguish it sufficiently from simple water. Mr. Boyle therefore calls this the neutral spirit of the subject.

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The oils of our ſubjects are next to be conſidered. Theſe are more compounded ſubſtances than the ſpirits. We have ſhewn the ſpirits to be diviſible by diſtillation into water and another ſubſtance, to which they owe the properties, that give them the denomination of ſpirits. The oils upon diſtillation ſend out into the receiver a quantity of oil in all reſpects like that diſtilled, except only, that it is more tranſparent and lighter; and with the oil in this rectification comes over, during the whole time, a portion of ſpirit, ſimilar to that yielded by the ſubject, whence the oil was drawn. It is to be obſerved, that this ſpirit does not come out of the oil with the firſt heat, before the oil riſes; but oil and this ſpirit come together to the very end of the diſtillation. After the diſtillation is finiſhed, a dry black coal is left behind.

If the oil brought into the receiver be diſtilled again, it divides as before. This perpetually ſucceeds in like manner, how often ſoever the diſtillation is repeated; excepting that the ſpirit approaches nearer to ſimple water. The oil therefore is diviſible into a black coal, and water, tinctured at firſt with the ſpirit of the ſubject, whence the oil is drawn. Theſe will not mix together again, and recompoſe the oil:

the reaſon of this is, that beſides theſe two viſible ſubſtances there is another, which flies off continually in an inviſible vapour, whoſe aſſiſtance is neceſſary to the compoſition of the oil. How to meaſure the quantity of this vapour, and make ſome diſcovery of its properties, will be ſhewn hereafter.

A thick balſamic juice naturally runs from many plants, ſuch as fir, yew, box, and the like. All the evergreens abound with theſe balſams, by which they are defended from the winter's cold. Theſe are uſually diſtilled with a leſs degree of heat, and in diſtillation divide juſt as the oils do.

This is largely practiſed in turpentine. It may be diſtilled in a retort, if it be firſt made a little warm, that it may be poured through a funnel into the retort without ſoiling the neck. This retort may commodiouſly be ſet in ſand, and a ſmall fire applied at firſt, and increaſed gradually afterwards. At the end of the operation, will be found in the receiver a quantity of oil and an acid ſpirit. If the operation be ſtopt, before the turpentine is dried to a coal, a tranſparent ſubſtance remains, brittle when cold, though melted with a ſmall heat. This is called colophony or black roſin. The oil, that firſt diſtils over, is finer, than what follows: and

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by rediſtilling the oil, it may be obtained yet finer. This oil, when brought to a great degree of fineneſs, is called the etherial oil of turpentine, and often, though improperly, the ſpirit of turpentine.

The thick ſubſtance remaining, after diſtilling from the oil its fine ethereal part, is called the balſam of turpentine.

The finer part of the oil will riſe from the turpentine with the heat of boiling water and leſs; thoſe therefore, who diſtil great quantities of turpentine to obtain the fine oil, diſtil it in a copper ſtill with water, after this manner.

The turpentine being put into the ſtill with a large quantity of water, the water is made to boil, and the vapour is condenſed by paſſing through a worm-pipe encompaſſed with cold water, after the manner I formerly deſcribed, when I ſpoke of chemical veſſels. The oil comes over with the vapour, and is ſeparated in the diſtillation by a glaſs of a particular contrivance called a ſeparating-glaſs, the form of which, and its manner of working we ſhall by and by ſee.

What is left of the turpentine, when all is drawn from it, which the heat of boiling water

will raiſe, is, when cold, of a brittle conſiſtence. This is yellow roſin.

Turpentine diſtils from the tree while growing, from wounds made in it for that purpoſe. While the tree is burnt, a coarſer juice runs from it. This is tar.

The method uſed for making tar is this. They make a floor with clay, or the like ſtiff earth, with a little declivity toward one part. Upon this they heap a pile of wood, and cover it with earth, as in making charcoal; leaving a ſmall vent only, that the wood may burn ſlowly. During the wood's burning, the tar runs away, directed by the declivity of the bottom.

In the latter part of the operation, the tar becomes coarſer than at firſt. This they convert into pitch in this manner. It runs into its receptacle ſo warm, that by the application of a live coal it will take fire. They ſet it thus on fire, and ſuffer it to burn, till it is brought to a conſiſtence, which will harden, when cold. Pitch is alſo made by boiling tar to a juſt conſiſtence.

The fine oil of turpentine is not the only one, for obtaining which boiling water is employed.

It is to be obſerved, that there are in plants two kinds of oil. One enters the compoſition

of the ſolid parts; another is lodged in certain veſicles or cells fitted for its reception, after the manner as the fat of animals is collected within the cells of the membrana adipoſa: and there are methods of ſeparating this latter oil, without any mixture of the former.

Some of theſe oils will riſe with the heat of boiling water. In this caſe the plant is put into a copper ſtill with water, and the oil diſtilled from it in the ſame manner as in turpentine.

Theſe oils, partaking much of the flavour and ſenſible qualities of the plant, are called the eſſential oils of the plants, whence they are drawn.

They agree in their medicinal virtues more with the plant, they come from, than any other chemical production does with the ſubject, from which it is extracted. Indeed as they are drawn with a ſmall degree of heat, ſo they exiſt in the plant almoſt, if not quite in the ſame form, as that they came over in.

The greateſt part of theſe oils are lighter than water; but that is not the cauſe of their riſing with ſo ſmall a heat; for ſome of theſe, ſuch as the oils thus diſtilled from many ſpices, are heavier than water; but the volatility of theſe oils is owing to the ſubtle ſpirit lodged

in them; for all these oils have a pungent smell.

The oils of other plants, where this volatile spirit is wanting, though they are much lighter than water, will not be thus separated. But these are obtained by pressing the subject between two iron plates. If the plates be a little warmed, more oil will be extracted; but, if they have given to them any considerable heat, the oil expressed will soon turn rancid. This is the reason, that physicians always prescribe these oils *sine igne expressa*. The safest method to liquify the oil, and facilitate its flowing from the subject, is to soke the subject a little while in warm water.

The seeds of plants, that abound with oil, are the only proper subjects for this operation.

In distilling the essential oils as before described, the vapour, which brings over the oil, is also in some measure impregnated with it, and therefore the water itself appears of a milky hue, and partakes of the smell and taste of the oil. We have asserted of oils, that they do not mix with water. But here the subtile spirit, which renders these oils volatile, communicates itself largely to the water, and retains with it a small portion of the oil. For this reason, in distilling these oils, it is most profitable to make use of

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the water before employed in diſtilling the ſame ſort of oil, for this water being already impregnated, will imbibe much leſs of the oil, than freſh water would do. It is alſo advantageous to ſet the ſubject, to be diſtilled, to macerate ſome time in the water kept warm, before it is drawn off; for by this means the ſubject is ſoftened, and will part with more oil than otherwiſe it would do. The diſtillation may be ſo long continued, till the water ſhall come off acid; the moment this is perceived, the operation muſt be ſtopt; for this acid will not only prejudice the flavour of the oil, and of the preceding water; but may chance in its paſſage to corrode the copper alembic, and give them an emetic quality.

There is another method of obtaining from plants a water endued with the flavour of their oil. This is not now much in uſe; but it is performed by the cold ſtill deſcribed in a preceding lecture. In this method freſh plants are diſtilled without any additional water. But here the watry part of the plant is cauſed to aſcend, impregnated with the flavour of the oil. This proceſs of preparing diſtilled waters being very tedious is much out of uſe.

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vapour with their virtues, and what do not. The ignorance of this has occasioned great absurdities in medical prescriptions. The only plants, whose distilled waters are of any efficacy, are those, from whence an essential oil may be extracted by distillation with water. In other plants the distilled water differs little, from what comes immediately out of a pump, or a river.

In like manner, when any animal substance is boiled in water, the vapour, when collected, differs in nothing from pure water, but in the smell, which is like that, we have in broth. If the boiling be long continued, this smell becomes fetid. But the water has acquired neither colour nor taste. This shews the mistake of those, who have expected great medicinal virtues in waters distilled off from animal substances.

As some of the oils of vegetables are volatile in the manner now described; so also are some resins from the same cause. From the gum called benjamin sublimes with a small heat a volatile resinous part in the form of white flowers. Camphire, as brought to us from the East, is wholly volatile, except what feculencies may remain in it. With a very small heat it may be sublimed into flowers; and by the use

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of a veſſel before deſcribed, called an infernal glaſs, a greater heat may be uſed, ſo that the camphire ſhall fix on the upper part of the glaſs in the conſiſtence of a ſolid cake; and this is the way, wherein camphire is ſublimed to purify it for ſale.

We have thus now gone through the analytical proceſſes uſually performed by chemiſts on animal and vegetable ſubſtances by ſimple heat only.

LEC-

LECTURE VIII.

HITHERTO I have considered no other use of the fire than by heating the subjects under examination in a close vessel, by which the effects of pure and simple heat upon these substances are seen.

As heat dilates and rarifies all bodies whatever; so these being heterogeneous, do not expand uniformly, and the different substances, of which they are compounded, being some more freely rarifiable than others, are gradually separated from each other. A great part of the most solid of these subjects appear under a fluid form, when separated from the rest. We find common water to be the basis of these fluids. The spirits are only water impregnated with some active principle, and the oils divide into water tinctured with the spirit of the subject, whence the oil was drawn, and into a dry earthy part. The solid parts, into which these subjects divide, are of two kinds; one that will unite with water, another that will not.

In this analysis of these subjects we are to consider the heat as producing no other change in the bodies,

bodies, than making a separation of parts before united. If it be asked, why then cannot we reunite them again? I answer, not only that the texture of these organical bodies is injured by this separation of their parts; but also, that, as besides the visible parts into which the body is divided, there is also another, that goes off in vapour, in this is carried away the vinculum, which held the parts together. What this vinculum is, and what its powers of action are, will gradually be made appear, in the course of these experiments.

All the subjects, I have treated of in my two preceding lectures, yield this vapour so plentifully, that in distilling them, were the junctures of the vessels to be absolutely closed, the vessels could not escape being broke.

The consideration of this aerial vapour is a new thing in chemistry. The diligent author of the Vegetable Statics has made many well-chosen experiments concerning this matter. Before him the subject had been but very superficially examined; though it is very worthy our attention; for by the assistance of some experiments to be proposed hereafter, it will give us no small light toward discovering the nature of the air we breathe.

This

This vapour expands by heat, and contracts by cold, as the natural air does. It has the same specific gravity, and the same degree of elasticity, whereby it resists compression.

The quantity of this air, which arises from the substances distilled, is very remarkable. From hartshorn there arises one-seventh of its weight in air; which comes with the white fumes, and continues to issue forth to the end of the distillation.

From solid oak is to be raised one-fourth of its weight of air, and from other vegetable substances, it arises in greater proportion. From tartar is to be obtained in air one-third of its weight.

Oils upon distillation afford plenty of this air. It is remarkable in the distillation of oils, that the water or spirit, which we have already shewn to separate from them, does not rise singly, and come all of it in one part of the distillation, but during the whole distillation oil and this water rise together; at the same time air disengages itself from the oil. By this it should seem, that this air contains in it not only the instrument by which this water and the earth left behind were before inflammable; but that by which they were united together in the form of oil.

And

And hence it is alſo probable, that in the diſtillation of more compound ſubſtances, a part, if not all of the ſpirit, which comes from them, exiſted in the ſubject in the form of oil, out of which ſpirit is produced in the diſtillation by the air's diſengaging itſelf.

And this collection and examination of the inviſible vapour ariſing in diſtillation completes the inquiry into the effects of ſimple heat on animal and vegetable ſubſtances, in a cloſe veſſel. To finiſh the chemical analyſis of theſe ſubjects we muſt proceed to examine, what farther operation the fire will have upon them in the open air.

We have ſeen all animal and vegetable ſubſtances reduced to a black coal by diſtillation, and this is the ultimate effect of ſimple heat only, except perhaps at length to render the whole volatile; but, if freſh air be admitted upon the coal, while hot, another appearance is ſoon obſerved. The coal quickly loſes its blackneſs, and for the moſt part falls to aſhes, whereas before, under the ſtrongeſt fire, it retains its original form.

By this we learn, that with the ſubſtance, which tinges the coal black, goes off the principle neceſſary to hold the ſolid parts of the coal together. The coal of all vegetable ſubſtances falls

falls to ashes as soon as the blackness disappears. One or two animal substances, as the teeth and the hardest part of the horns, retain their figure, even after they are become white. All other animal substances fall to pieces like vegetable substances.

By this we learn, that the principle, whereby the parts of these bodies are held together, is different from that, to which the coal owes its blackness; or at least that in the most compact animal substances a less portion of it, than what will tinge the coal black, suffices to continue some degree of cohesion. Which is the true cause will be better judged of hereafter.

The coal of vegetables, if once set on fire, will continue burning of itself, till reduced to ashes, without the assistance of any external heat, though the coal of the acid family of plants burns most vigorously. And from hence we learn further, that this substance, which tinges the coal black, is that, by which bodies are rendered inflammable. Before the conclusion of these lectures we shall see, that this principle, which renders all bodies inflammable, that are so, is found in all compound bodies whatever, and is the very same in them all, though all are not impregnated with so large a share of it, as to be rendered inflammable thereby.

by. The coal of ſome animal ſubſtances will ſcarce burn of itſelf without the aſſiſtance of external heat.

Charcoal is this black remains of vegetables, whoſe manner of making we have already deſcribed.

Again, the coal of thoſe vegetables, which yield in diſtillation acid parts, leaves after burning in its aſhes two different ſubſtances, that are ſeparable one from the other by boiling the aſhes in water. If the aſhes of the other ſubjects are boiled in water, the water, when ſeparated again from them by the filtre, brings away nothing from the aſhes; but in this the water will be found impregnated with a ſalt. This ſalt is ſeparable from the water by evaporating the water; for the ſalt will ſtay behind.

This ſalt may be obtained from plants, that yield it, without diſtilling them; by ſetting the plant, when dry, on fire in a clean furnace, and collecting the aſhes; for theſe aſhes will afford the ſame ſalt by being boiled in water. In all caſes to extract this ſalt to the greateſt advantage, it is proper to put the aſhes, after they have ceaſed burning of themſelves, into ſome proper veſſel, and by a ſtrong fire to keep them glowing hot, open to the air, for ſome hours.

This ſalt, when firſt extracted from the aſhes, uſually appears browniſh; but by being expoſed for a time in a due degree of heat it will become very white. This ſalt is an alkali, not volatile, as that from animals, but endures ſo ſtrong a fire as to melt. If melted, or fluxt, for a conſiderable time, it waſtes continually, and at length grows ſo ſubtle, that it cannot longer be contained in any veſſel. During this operation it uſually changes colour, firſt becoming green, and afterwards reddiſh; but theſe changes perhaps ariſe from ſparks of coal, which accidentally fly into the melting pot. I think the pot may be covered ſo cloſe, as to prevent this change, and theſe colours will burn out and return again. This ſalt has always a fiery taſte, and grows by long continuance in the fire a very ſtrong cauſtic, ſo as, when laid upon any part of the body, and covered cloſe over it, to burn it like an actual fire. Therefore, when uſed internally as a medicine, it ſhould not be too highly calcined. When white it is abundantly hot enough. This ſalt is found in all the acid plants: that extracted from wormwood is moſt uſed in medical preſcriptions; but there is no difference at all in the ſalt, from whatever plant it be extracted. As the volatile animal ſalt is the ſame, from whatever ſubject it is diſtilled, ſo

so this salt is in all vegetables, where it is found, the very same: though many have absurdly ascribed to these salts all the particular virtues attributed to the plants, whence they are drawn.

If this salt, after it has been melted in the fire, be dissolved in water, and filtred, it will leave a quantity of earth in the filtre. The like it will do, how often soever the operation be repeated. From hence we may learn, that this salt is an earth, which has some other substance united with it, by the intervention of which it dissolves in, and is united with water; which substance the fire at each melting expels out of some part of the salt.

This salt, as has been said, is very fixt, as the other of animals was found to be exceeding volatile.

These are the two alkaline salts, besides which there is not known any other. Nor do they appear to differ in any other circumstance, than that of volatility only; excepting, that the volatile salt cannot be kept so long in the fire, as to be so much freed from the adhering oil, as the fixt salt may; by which means the volatile salt will not dissolve in water quite so freely as the other.

This salt, extracted in the manner as has been described, is not perfectly pure. If it be dis-

This salt, when first extracted from the ashes, usually appears brownish; but by being exposed for a time in a due degree of heat it will become very white. This salt is an alkali, not volatile, as that from animals, but endures so strong a fire as to melt. If melted, or fluxt, for a considerable time, it wastes continually, and at length grows so subtle, that it cannot longer be contained in any vessel. During this operation it usually changes colour, first becoming green, and afterwards reddish; but these changes perhaps arise from sparks of coal, which accidentally fly into the melting pot. I think the pot may be covered so close, as to prevent this change, and these colours will burn out and return again. This salt has always a fiery taste, and grows by long continuance in the fire a very strong caustic, so as, when laid upon any part of the body, and covered close over it, to burn it like an actual fire. Therefore, when used internally as a medicine, it should not be too highly calcined. When white it is abundantly hot enough. This salt is found in all the acid plants: that extracted from wormwood is most used in medical prescriptions; but there is no difference at all in the salt, from whatever plant it be extracted. As the volatile animal salt is the same, from whatever subject it is distilled, so

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ſolved in water, and ſet by in a cool place, a ſalt of a different kind will ſhoot from it. Some of the water being evaporated, more ſalt of the like kind will ſhoot. At length no more of this ſalt can be produced, and the water being wholly evaporated, the fixt alkali ſalt will be obtained pure.

The fixt alkaline ſalt, I have now under conſideration, is not to be prepared, but from ſubjects, wherein both an acid, and an oil, or inflammable part may concur to the production of it. Of this we ſhall have a remarkable proof in preparing this ſalt from nitre or ſalt petre. To the acid it owes its power of diſſolving in water, and to the inflammable part its melting. The more this oily or inflammable part abounds in it, the readier it melts. Tachenius propoſes a method of preparing this ſalt by heating the plant in a pan or a pot covered over, ſo as to prevent in a great meaſure the acceſs of air to it, and by this means a ſalt is produced more impregnated with oily parts, and much more eaſily fluxible, than when the plant burns more freely, as in the manner before mentioned of producing this ſalt.

Theſe ſalts are made uſe of in great quantities in ſeveral trades, viz. by the dyers, ſoap-boilers, and the makers of glaſs. All theſe uſes we

we ſhall explain in the courſe of theſe lectures; but here is the proper place for deſcribing, how the great quantities are made.

Theſe ſalts, according as they are more or leſs purified from the earthy and oily parts of the plant, go by different names. The ſalt called pot-aſhes is thus made.

The aſhes of wood are firſt boiled in water, till the water is ſtrongly impregnated with the ſalt of the aſhes. In this tincture, or, as it is uſually called, lye, are ſteeped the ſtalks of beans, and ſuch like vegetables, of a middle texture between ſoft leaves and firm wood, and from this carried to a hearth incloſed with brick work, and there ſet on fire: as they burn, the fire is kept up by a continual ſupply of the ſame fuel. As theſe parts of plants abound with ſalt, and are ſtill more charged with it by ſoaking in the forementioned lye, the ſalt notwithſtanding the earthy part remaining with it, melts and lies fluid at the bottom of the hearth, all the time the fire is kept up. Theſe ſucculent parts of plants alſo abound with oily parts, whereby the ſalt thus prepared reſembles moſt, that prepared after Tachenius's method before deſcribed; and like that, melts in the ſmall heat of theſe hearths. This ſalt is uſed by the ſoap-boilers, and by the dyers.

This salt is not so white, as some other sorts of it. The whitest is called pearl-ashes, and is made from the ashes of vegetables by extracting the salt with water, and then calcining it in a furnace like that, in which red lead is made, which we shall describe hereafter. The fire, by which this salt is calcined, is not attended with any expence; for the ashes of the fuel will serve to make more of the salt.

Thus I have described the result of burning, as far as relates to those parts of the plants, which stay, and endure the fire. Its effects upon the volatile parts are no less remarkable; for the soot, into which the smoke condenses, (though the plant be of the acid kind) affords upon distillation a volatile alkaline spirit and salt, such as simple distillation produces from the other species of plants: and the phlegm, which first rises, has the like fetid smell, as the water of the alkaline plants.

We shall find, that putrefaction produces the same change in these plants. But thus far burning differs from putrefaction, that in burning, though this volatile salt is found in the soot, yet the ashes retain a large portion of fixt salt, though not altogether so much, as when the plant has been distilled in a retort before calcination. In putrefaction, if it be permitted

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to proceed, till it is become perfect, there is scarce any fixed salt left in the subject.

Now we have gone through the common analysis of animals and vegetables. In animals we have found a quantity of water plentifully lodged even in their dryest parts. This water we found impregnated with a volatile substance of an alkaline quality; the same substance we have seen likewise under a solid form. Besides these we had a thick oil and a black coal, which by burning becomes a mere white earth.

In some few vegetables, we found the same principles. And all vegetables after putrefaction, exhibit entirely the same substances as animals do. Otherwise the greatest part of vegetables, yield very different principles.

The water which comes from them, besides a very pungent smell remarkable in it, is strongly impregnated with acidity. Two oils were also found in them. One separable from the solid parts; the other, which we called the essential oil of the plants, is chiefly, what is lodged in particular cells of the plant, and collected together there in the form of oil, while the plant is growing, just as the fat of animals is contained in membranes prepared expressly for its reception. Besides these parts extracted from vegetables, there remains a black coal, which

calcined falls to ashes; and in the plants, where principles are found analogous to those of animals, these ashes are a mere earth; in the others they contain a large quantity of a salt, which remains very fixt in the fire; whereas the salt found in animals, and in the other species of vegetables, is exceeding volatile.

This fixt salt is also an alkali, as well as the other, though it be found in plants, which abound with the acid principle. We mentioned, that this salt is only producible from subjects, wherein are found both acid and inflammable parts. Sir Isaac Newton was the first, who perceived, that these fixt alkali's were an earth with an acid adhering. To the acid in this salt (as has already been observed) is to be ascribed its power of uniting with water, and to the inflammable principle its melting in the fire. But its union with water is in part obstructed, while any gross oiliness remains in the salt; and the more effectually that is driven out by the fire from any of these salts, so much the more strongly does the salt draw moisture to itself. Insomuch that, when an alkaline salt is calcined very high, it draws the natural humidity of the air so potently, that it is difficult to keep it dry. However we have found, that at length the principle, which unites the earthy part

part of the ſalt with water, will be alſo expelled by the fire.

The oils of all theſe ſubjects we have found to be a union of two ſubſtances, earth, and water a little tinctured with the ſpirit of the ſubject. We muſt farther obſerve, that ſo much of the oil, as is thus divided, has loſt its inflammability; and we have juſt deſcribed a proceſs, whereby it appears, that during the diſtillation an inviſible ſubſtance eſcapes under the form of an aerial vapour. In this ſubſtance therefore we muſt ſeek for the principle, whereby the oil is rendered inflammable. Therefore as the coal both of animal and vegetable ſubſtances is an earth joined to an inflammable principle, ſo the oils of theſe ſubjects are a compoſition of earth, and water tinctured by the ſpirit of the ſubject united with the like inflammable principle.

LECTURE IX.

THE nature of the principles, into which bodies are reduced by the fire, will be best understood by the effects of two natural operations, the fermentation incident to vegetable juices, and the putrefaction common both to vegetable and animal substances.

Fermentation is a change, which ripe juices are disposed of themselves to undergo, whereby an intoxicating spirit is first produced, which was not before in the plant, and at length the fermentaion ends in vinegar.

This fermentation is properly an action between the acid, and the other parts of the juices, principally their oil, whereby the oil is attenuated, and so united with the acid, as to be dissolvible in water: in the mean time it retains the inflammability proper to oil; nay has increased it. But at length the acid so far prevails, that the liquor, now become vinegar, will burn no longer, but will quench fire.

A certain proportion and union between the acid and oily parts is requisite to promote this action of fermentation.

A due mixture of acid and oily parts produces ſweetneſs.

Sugar will burn, therefore has received ſome oily parts from the juice, whence it is made, and upon diſtillation it yields an acid ſpirit. The like acid ſpirit is produced from honey, which is alſo an inflammable ſubſtance. This compoſition of acid and oily parts is that, which is moſt conducive to fermentation. For this reaſon we ſee the ſweeteſt juices, as that of grapes, are diſpoſed, when preſſed out in large quantities, to ferment of themſelves. On the other hand unripe juices, that have a rough auſtere taſte, will not eaſily ferment. Alſo thoſe, which abound with oil to ſuch a degree, as to loſe their ſweet taſte in a flat oilineſs, and thoſe juices, wherein the tart taſte predominates, ferment but ſluggiſhly.

Not only the expreſſed juices; but alſo the juices drawn from ſeveral parts of plants by infuſing them in water, will alſo ferment, as we ſee done in barley in the making of beer.

But here the grain is firſt to be prepared, that the oily and acid parts may be ſo united together, as to produce the ſweetneſs, we have obſerved to promote fermentation. The grain is firſt macerated ſometime in water, then the water is ſeparated from it, and the grain laid in heaps,

till

till it begins to grow: after this it is dryed with a gentle heat, and the grain is found to have acquired a saccharine sweetness.

When a vinous liquor is to be made of this grain, water of a somewhat less heat, than that wherewith it will boil, is to be poured upon it. The common test, I think, for the heat of the water, is to wait, after it has once boiled, till the steam is grown small enough not to hinder the water from making a sensible reflection of the person, who looks upon it. When the grain has stood infusing some time, the liquor is strained off, and, when cool, mixt with some material proper to quicken the fermentation.

In the making of wine, that juice ferments usually without help; the only operation it undergoes, previous to its fermentation, is in the rendering the wine red. There the juice is two or three times successively infused upon and pressed strongly from the husks of the grapes, which are of the red kind; and from these husks the wine receives its tincture.

Fermentation proceeds thus. The fermentable liquor being put into a vessel in a place moderately warm, it soon begins to swell, while bubbles break from it, and a whitish frothy head forms itself over it. This head at length condenses

denſes and ſinks, and becomes the lee, the fermentation ſtill continuing. From this time the vinous ſpirit leſſens by diſſipation, and the fermentation being kept up terminates in vinegar. If the liquor, as ſoon as the white head ſinks, be drawn from it, and put up in a cloſe veſſel, the fermentation will be checkt, and the liquor will remain for a long time in the ſtate of wine. But wine is continually changing, though by ſlow degrees, till at laſt it ends in vinegar. The genuine part of the wine-cooper's ſkill is principally to reſtrain the progreſs of the fermentation, as long as poſſible, but at length no art can prevent it.

All the time the liquor is in the ſtate of wine, an obſcure fermentation proceeds, whereby it acquires more ſpirit, and continually depoſits lees. Theſe lees keep up the fermentation, and when ever it grows too ſtrong, the moſt effectual ſtep to check it is to draw the wine off from its lee.

The wine, during this ſtate, likewiſe continually depoſits a ſaline cruſt, which adheres to the ſides of the caſk containing it. This ſaline matter is called tartar or argal. At length the wine depoſits the moſt part of the oil in the form of a mucilagineous ſediment, and then becomes

comes vinegar. Thus when wines turn ropy, we know they are very near being ſour.

Only the juices of the acid ſpecies of plants ferment, the juices of the alkaline plants putrefy.

It has already been mentioned, what theſe fermentable juices yield upon diſtillation, before they are fermented, viz. an acid ſpirit, oil, and a black coal, from whence a ſalt may be extracted by burning it in the open air, as from the remains of all the acid family of plants. When wine is diſtilled, the firſt thing which riſes from it, is a very volatile ſubtle fluid, of a very peculiar kind. It will mix freely with water, and yet burns like oil, nay with a much fiercer heat. This ſpirit is not only exceeding volatile, when ſeparated from the wine; but alſo riſes from it with leſs heat than, what would raiſe any thing from the juice before its fermentation.

This ſpirit riſes mixt with much water, from which it may gradually be ſeparated more and more, by ſubſequent diſtillations in tall glaſſes, and with a very gentle heat: as it is more and more freed from its aqueous parts, it increaſes greatly in volatility.

(Here explain the manner of taking the proof of ſpirits.)

This

This spirit being well freed from its watry part, it burns all away, when once set on fire, without leaving any remains behind whatever. If it be burnt under a tall vessel, so contrived as to collect the vapour, which rises from it in burning, that vapour is found to be mere water. Hence we learn, that this spirit is water united with that subtile part of the oil, from which oil receives its inflammability, and which we shewed in the last lecture to fly from it by repeated distillations.

Hence we may learn also the cause of what is observed in the distillation of honey and sugar, which Mr. Boyle was at a loss to explain, that though these substances are inflammable, yet they yield scarce any oil upon distillation; for as these substances contain only that portion of the oily parts, which is convertible into spirit, so by distillation we find, they contain no more oil, than what loses its form in one distillation, by the dissipation of the subtile part, to which its inflammability, and the form of oil are owing.

After all the forementioned spirit is distilled off from the wine, the remains yield the same principles, as the juice would have done before fermentation.

When

When the liquor approaches towards vinegar, it yields again leſs inflammable ſpirit; inſomuch, that when the vinegar is completely made, it affords none at all; but upon diſtillation the firſt liquor, that riſes, is an uninflammable acid ſpirit; and by continuing the diſtillation, the more acid does the liquor grow, that comes off. At length what aſcends, becomes oily, but ſtill is acid, as will alſo the remains be. Theſe remains burnt in the open air yield a ſalt of the ſame kind as that, which is producible by burning from all the plants, that yield acid principles in diſtillation.

If tartar be diſtilled, it produces no inflammable ſpirit, but yields altogether the ſame ſubſtances as the acid plants afford; that is a pungent ſpirit impregnated with acidity, an oil, heavier than water, with a very ſmall portion of a light oil and a black coal, which being ſet on fire in the open air yields alſo the forementioned ſalt.

By this diſtillation of tartar we ſee, that it contains thoſe parts of the juices in which the fermentation has made no change, being only depoſited from time to time from the other parts of the juice, whereon the fermentation operates.

Such

Such a ſaline ſubſtance, as this, will ſeparate from the juices of plants without their fermenting. It may be produced in the following manner. After the plant has been bruiſed, and the juice preſſed out; the juice is to be ſet by for ſome time to ſettle: after which let it be ſtrained, that the liquor may become clear, and then be evaporated over a gentle fire to the conſiſtence of a thin ſyrup. Let the juice thus prepared be ſet in a veſſel in a cool place, and at length a ſalt will ſettle about the ſides of the veſſel, while a feculency ſubſides to the bottom. An unglazed earthen pan is the fitteſt veſſel for this purpoſe, that the ſalt may be aſſiſted in its adheſion by the roughneſs of the veſſel. The liquor muſt alſo be covered over with clean oil to keep it from the contact of the air. Otherwiſe the juice will not be preſerved, but be changed by fermenting or mouldineſs.

Theſe ſaline ſubſtances are uſually called the eſſential ſalts of the vegetables, whence they are produced, and tartar is very properly to be called one of them.

Tartar diſſolves in water with difficulty, and will not remain diſſolved in it, unleſs the water be almoſt of a boiling heat. As ſoon as the water is cold, the tartar almoſt intirely quits it again, the earthy part ſubſiding, while the ſaline

part shoots on the bottom and sides of the vessel, and a small saline crust swims on the top. This crust on the top is properly called the cream of tartar, and the shootings, the crystals; though these also, which, differ nothing from the other, but in the place, where they are collected, are generally comprized under the name of cream of tartar.

In preparing these crystals, the tartar should be boiled in much water.

When the tartar is first dissolved, the water appears very dirty; and the crystals separate so soon, that they do not admit of so slow a filtring, as would be necessary to purge the liquor intirely from this dirt. It can only be strained through a cloth. But when the crystals are shot, as they will not dissolve in cold water, what dirt has passed the strainer, and remains loose among them, may be washed away by the affusion of cold water.

Thus may the tartar be freed from its gross earth. But the intire purification requires a particular artifice. It is done after the tartar has been separated from its gross dirt, as now described by boiling it again with a small quantity of a certain earth, which will not render the tartar much more dissolvible in water; but yet separate from it a sufficient portion of its oily

and

and terrestrious parts; from which it receives its brown hue.

The distillation of tartar makes manifest, why it dissolves in water with so much difficulty; for that shews the tartar not to be a simple salt, but to have a great redundancy of oily and terrestrious parts joined with it.

Tartar, and the other called essential salts, are so named, because they are supposed to exist in the juice of the plant, as they appear to us. But they rather seem to be produced from the liquor by a new combination of parts; for at first the whole of the juice will more easily dissolve in water than these salts.

After this description of the effects of fermentation, we may judge in some measure, wherein this remarkable operation of nature consists. When this operation has proceeded in full vigour, we find, the acid has so far disengaged itself from the other parts of the juice, as to manifest itself more conspicuously, and pure, than it can be obtained by any other means. But of all the parts of the plant, the oil is more particularly affected by this fermentation. It is no sooner begun, but the quantity of oil is diminished, and in its stead an inflammable spirit produced, which will mix with water. It appears therefore, that the inflammable part of the juice,

or its oil, is so dissolved and united with the acid, as to be capable of mixing with water. By a longer action of the acid, when the liquor becomes vinegar, the oil is then so much farther altered, as to lose even its inflammability.

When the liquor is drawn from its gross lee, and closed up in a cask, before the fermentation is finished, it proceeds then slowly. But however by the liquor's gradually depositing some of its earthy and oily parts in the form of tartar and lee, the acid at length will so far prevail as to carry on the fermentation even in a close vessel, till the liquor becomes very sour.

This fermentation (by the wine-coopers commonly called fretting) whereby the wine runs to vinegar, is usually considered under the notion of a second fermentation, as if it were an action of a distinct nature from the first; but I apprehend, this is no otherwise a second fermentation, than because the first part of the fermentation has been restrained by art; since, if the fermentation was sufficiently strong at first, and not interrupted, the liquor, after a time, heats, the inflammable spirit is dissipated, and the fermentation ends in vinegar, before it ceases: nay sometimes, in very hot weather, the distillers find, to their great loss, that no art can stop it sooner.

It is uſual indeed, when it is deſired to make vinegar of wine, to promote the acetous fermentation by art, mixing the wine with its own lees, with vinegar, or with tartar; or putting the wine into a caſk, that already has held vinegar, and other the like means will produce this effect.

Likewiſe, when the fermentation at firſt proceeds too ſlowly, it may be promoted by art. Such juices, as ferment but heavily, may be quickened by adding ſuch as have a greater facility in fermenting.

The juice of grapes, hindred from fermenting by impregnating it with the ſmoke of ſulphur, put to wines, will excite a fermentation in them. This is made uſe of by wine-coopers, when they mix different wines together; for unleſs the wines after mixing ferment, they will not unite into one uniform taſte. Other materials are too often made uſe of for this purpoſe, which clog the wine, and make it diſagreeable to the ſtomach; but this being a vinous juice is no prejudice to the wine. A little of that head, we obſerved to riſe upon fermenting liquors, will gradually promote fermentation, being generally uſed by the brewers for that end; and it will do the ſame after it is ſubſided, and become lee. All the purgative reſins will likewiſe pro-

mote fermentation. Jalap is moſt uſed by the diſtillers, becauſe it gives no taſte to the ſpirit.

On the other hand a mixture of acids or alkalis, ſo as to deſtroy that balance between the acid and the reſt of the juice, which is moſt conducive to fermentation, will give a check to it. The ſpirit diſtilled from wine checks fermentation very powerfully. Theſe ſpirits are one pernicious ingredient in all adulterated wines; for when heterogeneous materials have been mixt together, which would fall into a violent fermentation, it is neceſſary to add a large quantity of ſpirits to reſtrain it.

Why this ſpirit is ſo powerful a reſtrainer of fermentation, is the reſult of the effect it has upon acid ſpirits. The fume of ſulphur acts upon the ſame principle, and is often uſed for this purpoſe.

Upon the whole, we ſee, that the laſt effect of fermentation, is for the acid to operate upon, and prevail over all the other principles.

The unfermented liquor, called muſt, is ſweet. There the acid is intangled with the oil ſo much, that it can only affect the tongue and palate in the mild and agreeable manner, we call ſweetneſs. In fermenting it attenuates the oil, by which this ſweetneſs is gradually leſſened, till at length in vinegar it diſcloſes its

its genuine taſte, when diſentangled from thoſe oily and terreſtrious parts, which diſguiſe it.

From the diſtillation of vinegar we may learn, how firmly acids can adhere to other bodies: for here the acid in diſtillation accompanies the volatile parts, and aſcends with them, and alſo keeps joined to the more fixt.

(The calcination of tartar.)

Here in vinegar we find the vegetable acid in its greateſt perfection, and produced without the aſſiſtance of any chemical fire.

Thus by fermentation we ſee the ſame acid ſeparated from vegetables, as by diſtilling them.

By putrefaction the volatile ſpirit and ſalt are ſo ſeparated from the reſt of the compound in animal ſubſtances, that it may be obtained entire by no greater heat, than what is neceſſary to ſublime it. When thoſe ſubſtances are diſtilled freſh, a great degree of heat is neceſſary to diſunite the volatile ſpirit and ſalt from the other parts. But by putrefaction they are ſo diſengaged from the reſt, that they are ſeparated, and brought to view by no greater heat than what will ſublime theſe ſubſtances, after they have been extracted from the mixt. Therefore putrefaction alone has truly produced theſe ſubſtances out of the compound.

Thus we find by the two natural operations of fermentation and putrefaction the same substances produced out of mixt bodies, as are expelled from them by the heat of chemical fires.

Putrefaction will produce these volatile spirits and salts from plants also, even from those, whence the simple and unassisted heat of our fires produced only acid parts. Though it appears in the distillation of soot, that heat assisted by the air, will dispose these substances also to afford the like.

The leaves, and such succulent parts of all plants, if laid and pressed close together in a heap, when green and in a warm place, soon begin to putrefy. They first grow hot, even sometimes to the taking fire, and at length turn into a pappy consistence, which being distilled yields a spirit stored with volatile salt, to be drawn from it by rectification; and when this rectification has been repeated two or three times, the salt appears to be altogether the same with that, which comes from animal substances.

When the distillation is finished, what remains in the retort is a great deal less, than it is, when the plant is distilled, before putrefaction. The volatile salt also is much more in quantity, than the

the fixt ſalt to be drawn from the plant not putrified would be.

From plants thus putrefied there alſo comes off a black but light oil, reſembling that drawn from animal ſubſtances.

In the laſt place let it be obſerved, that in this putrefaction all the appearance of the acid is loſt.

It is alſo very remarkable, that the earthy part is much diminiſhed. It ſeems therefore, that the earth of the plant is partly turned into volatile ſalt. Let us alſo conſider, that the acid of the plant is now loſt; and we ſhall ſee here an effect conſonant to ſir Iſaac Newton's opinion of alkaline ſalts; for where is this acid retired, but into the other parts of the plant? In a word as fermentation is an action ariſing in the juices of plants, whereby the acid diſengages itſelf from the other principles ſo far as to unite more copiouſly with the watry part of the juice, whereby the acid manifeſts itſelf more than before; ſo here in putrefaction the earthy parts imbibe the acid ſo as to render it inviſible.

We ſee alſo operating in the ſame plant both the fermentation, which ends in vinegar, and putrefaction productive of alkaline ſubſtances. The inteſtine motion; which ariſes in the juice, where watry and acid parts abound, produces

vinegar, and in the plant itſelf, where its earthy parts exceed, the inteſtine motion cauſes putrefaction.

In the next place we learn from hence the nature of animal digeſtion; for here we may ſee, that the putrefying of vegetables works the like changes in them, as digeſtion does, when it converts them into animal ſubſtances: digeſtion therefore is, as it were, a begun putrefaction.

For this reaſon, the ſubſtances, from which we receive nouriſhment, are ſuch as are diſpoſed to putrefy; and thoſe ſubſtances, which putrefy ſooneſt, ſooneſt digeſt. Meats of hard digeſtion are rendered eaſier to digeſt by keeping. If they are kept ſo long as to be actually putrid, they are then indeed become unfit for nouriſhment, becauſe they are got beyond the ſtate, which the action of the ſtomach and bowels is to bring them to: digeſtion in the ſtomach is no more than an advance toward putrefaction; for we find, that vegetable diet, when in the blood, does not immediately part with its acid nature, which is the cauſe of that acidity, we obſerved to be in milk.

The firm union with the acid and terreſtrious parts brought about in putrefaction, and in animal concoction, whereby vegetable ſubſtances become part of an animal body; is the reaſon, why

in the oil of putrid vegetables, and in animals no visible acid is found, as in the other oils of vegetables. Here the acid is too strictly united to the earthy parts of the oil to be expelled from thence, and manifest itself. In other words it now adheres more firmly to the earthy than to the watry part of the oil.

In fermentation the action of the acid is to cast off the grosser terrestrious part from the rest of the juice; but here the action of the acid is to unite itself more firmly to the earthy parts of the vegetable, and at the same time to attenuate and render more subtle those terrestrious parts.

LECTURE X.

HAVING gone through the uſual chemical analyſis of animal and vegetable ſubſtances, the recompoſitions of thoſe ſubſtances, which have been contrived from them, whereby very valuable medicines have been introduced, and the nature and properties of thoſe ſeveral ſubſtances illuſtrated deſerve next to be conſidered.

Of the proceſſes therefore I now propoſe particularly to conſider, the firſt is the property of the lixivial ſalt extracted from the aſhes of vegetables to run into a water by attracting the moiſture of the air.

If a lixivial ſalt be highly calcined, it will ſcarce be cold, before it becomes damp, beginning to diſſolve by the moiſture of the air.

But all ſuch ſalts, if hung up in a bag, or laid upon a glaſs, will ſoon imbibe ſo much moiſture from the air as to run off in a liquor. This is the moſt effectual way to have the ſalt pure from any earthy part: for thus more earth will be left behind, than when it is filtred through paper.

This

This property of lixivial ſalt makes it very uſeful for rectifying ſpirit of wine; for if as much of this ſalt as amounts to about one third of the ſpirit be added to it, and then the ſpirit be gently diſtilled, it will riſe much freer from the phlegm, or watry part, than otherwiſe it would do; the phlegm being held back by the ſalt, this ſalt being diſſolvible by the water, but not by the ſpirit.

It muſt here be noted, that ſome ſalts are diſſolvible both by water and by this vinous ſpirit; others by water only. Of this latter kind is the fixt alkali, or the lixivial ſalt here under conſideration, unleſs, perhaps, ſome very ſubtile and inviſible parts of it, by which the ſpirit may be rendered by digeſtion with this ſalt ſomewhat more pungent. If the alkaline ſalt by melting has acquired a reddiſh hue, the ſpirit will receive a ſimilar tint from the ſalt. But this colour more properly ariſes from that, which coloured the ſalt, than from the ſalt itſelf.

When this fixt alkaline ſalt is mixt with any acid, it ſuddenly excites a very viſible fermentation: amongſt the reſt with the acid of vegetables, which appears leaſt intangled with other ſubſtances in vinegar, eſpecially after the vine-

gar

gar has been diſtilled, and thereby its moſt unctuous parts ſeparated.

If a little of this ſalt be thrown into vinegar, whether diſtilled or not, numerous bubbles, with a ſmall hiſſing noiſe, preſently ariſe, and the ſalt is ſoon diſſolved. Upon throwing in more, freſh bubbles appear. At length no farther commotion will be excited by caſting in the ſalt. And, if the ſalt be caſt in with a careful hand, neither will any fermentation appear upon adding freſh vinegar. But if heat be applied, the ſalt will ſtill ferment with an additional quantity of vinegar. Though, when about ſixteen or twenty times the weight of the ſalt has been added of the vinegar, no farther fermentation will appear, though the vinegar boil. If this be done with diſtilled vinegar, and the operation proſecuted with the following circumſtances a neutral ſalt neither acid nor alkaline will be produced very white. After the ſalt is ſo ſaturated, that no fermentation follows upon the affuſion of more diſtilled vinegar, the liquor is to be evaporated away, when a ſalt will be left foul and black, eſpecially if the operation be performed in an iron veſſel. This ſalt is to be melted for a little time, which is done with a very ſmall heat. Then, thrown into

water, it immediately diſſolves, and depoſits its blackneſs ; the water being evaporated, with care that no more heat be uſed at laſt, than juſt what is ſufficient to dry the ſalt, the ſalt will be left very white ; which muſt be immediately put up in a cloſe glaſs, for ſcarce any ſalt attracts ſo powerfully the moiſture of the air.

This ſalt has been called tartarus regeneratus, thought it differ ſufficiently from tartar. In the preſent Pharmacopœia it is named ſal diureticus, from its medicinal operation.

This ſalt is one of thoſe, which diſſolve both in water and ſpirit of wine ; and the criterion of its perfection is, that it diſſolves in either without depoſiting any ſediment. When rendered thus pure, the ſtomach bear a greater doſe of it than otherwiſe.

If, when this ſalt is laſt dried, ſo much heat is uſed as to cauſe it to melt, it will concrete into a foliated texture. But with ſo much heat it is difficult to preſerve its intire ſolubility.

This preparation is a valuable medicine. And there is an extemporaneous compoſition formed upon the ſame principles generally eſteemed. This is the juice of lemons mixt with a fixt alkaline ſalt : it is moſt uſual to join one part of the ſalt with about twelve parts of the juice.

Fixt

Fixt alkaline ſalt added to a ſolution of tartar or its cryſtals made in boiling water, produces alſo a kind of fermentation, of which we ſhall have more examples hereafter.

In the foregoing proceſs we ſee, the fixt alkaline ſalt excite a fermentation with the vegetable acid, when joined only to water. In this we find, the ſame alkaline ſalt ferment with the acid lodged in tartar, and ſeparate it from the earthy and oily parts of the tartar, and unite it with itſelf, thereby compoſing a ſalt diſſolvible in cold water.

By this we ſee, that the ſame acid may act with different degrees of force upon different terreſtrious ſubſtances. In tartar the union between the acid and the terreſtrious parts is ſo great as to render the whole, except ſome groſſeſt part of its earth, diſſolvible in water, and when the water is not hot enough to retain the tartar ſuſpended, the acid of the tartar ſtill retains its adheſion to the other parts of that ſalt, ſo that almoſt the whole ſeparates from the water without any diſunion. But here the acid quits its own earth, to take hold of the alkaline ſalt, whereby the other parts of the tartar, which before were ſuſpended in the water by the acid, are now in great part precipitated as earthy fæces.

The

The affusion of vinegar also upon many substances wholly indissolvible in water will raise the like effervescence.

By this effervescence with vinegar and other acids, these substances are usually rankt under the class of alkalis, by a name borrowed from a plant, which yields this salt plenteously. And under this head are ranged coral, chalk, oyster-shells, and all those called testaceous powders, all which excite this effervescence with acids and destroy their acidity. But all these substances are distinguished from alkaline salts by their not dissolving in water.

When distilled vinegar is poured upon coral an effervescence, as has been said, arises. If vinegar is thus gradually poured on, at length no farther effervescence will follow; but that the coral may be fully saturated, the mixture should be set upon warm sand, and stirred now and then, till the heat will raise no effervescence. The liquor being afterwards filtred, and so much of the coral as the vinegar has dissolved precipitated by a solution of an alkaline salt in water, the powder, which falls, is no longer dissolvible in water, and is called the magistery of coral. The liquor evaporated to dryness leaves behind a substance, that will dissolve in water, and is called the salt of coral. By this we may see,

that

that though coral is itself so much an earth, that it will not dissolve in water, yet the acid of vinegar, by uniting with a part of it, will render that part a true salt. Here therefore we have an instance of producing a salt by joining an acid to a mere earthy substance, wherewith it is disposed to unite.

How much this and other the like experiments conduce to explain the nature of salts, I purpose to consider farther hereafter.

LEC-

LECTURE XI.

WE are now upon the compositions usually made from the substances, which our preceding analyses have afforded us; and we have considered the effects of compounding salts, and saline spirits. We shall proceed to the operation of salts on oils, and inflammable spirits, and the action between these subjects themselves.

Lixivial salts act strongly on oils.

Common soaps, both soft and hard, are made by uniting oil and tallow with a solution of some lixivial salt in water. But, as the soap-boilers take into the operation the assistance of lime, I shall defer the farther explanation of this, till lime shall come under consideration.

The soap of tartar, a preparation first produced by a necessitous quack, though since greatly celebrated, is an attempt to unite the alkaline salt of tartar with oil of turpentine. What oil can be joined with the salt will soon be taken up with the help of a little warm water, notwithstanding the tedious processes usually re-

commended for this end, attended with cautions, which in reality are no other than endeavours to retard the effect. The direct method is to melt the ſalt, powder it hot in a warm mortar, and put to it an equal weight of oil of turpentine alſo warmed, and while they are rubbed together, adding about half the weight of hot water. They will ſoon unite, though time is required for the compoſition to acquire a due conſiſtence. This ſalt is ſaid to be capable of imbibing thrice its weight of oil. But from the ſoap of tartar after diſtillation and calcination will be left two-thirds of its weight of a ſimple alkaline ſalt; three-fourths of the other third being mere water: ſo great a part of this volatile oil employed in the proceſs, flies off again, before the ſoap receives its juſt conſiſtence.

The action between fixt alkaline ſalts and oil produces likewiſe another phænomenon. It has been formerly obſerved, that, when freſh urine is put to diſtillation, a great quantity of phlegm ariſes firſt from it: and the volatile ſpirit and ſalt are not to be raiſed without a ſtrong heat, as in the diſtillation of hartſhorn; becauſe a great force of fire is required to diſengage the volatile ſalt from the oil, to which it adheres; but if a large quantity of ſtrong alkaline ſalt be

added

added to the urine, by the ſtronger attraction, there is, between this ſalt and the oil, than there is between the volatile ſalt and the oil, the volatile ſalt is diſengaged, and permitted to aſſume its volatile nature, and riſe from the urine with a gentle heat.

Though fixt alkaline ſalt will not unite with ſpirit of wine, but imbibe from the ſpirit its watry part, as has before been ſaid; yet if the ſpirit be firſt very carefully freed from its phlegm, it may be made to take a reddiſh tincture from this ſalt. For this purpoſe the ſalt muſt be melted in the fire, till it has acquired a reddiſh hue, and be added to the ſpirit, while yet warm, that it contract not any humidity from the air.

This proceſs is attended with difficulty, the colour of the ſalt being probably owing to accident, as has been above explained; and ſeems to ariſe from a ſmall portion of oily parts, with which the ſalt is by chance impregnated. The practical chemiſts therefore uſually mix a little antimony with the fixt ſalt, whereby they are ſure of giving a tincture to the ſpirit; but the college of phyſicians have not thought the preparation worthy a place in their preſent diſpenſatory.

Another kind of compositions is made by ſpirit of wine, and oleoſe ſubſtances. Pure ſpirit of wine poured upon any eſſential oil, diſſolves it; and if it be diſtilled off from it, brings the pureſt part over with itſelf. Alſo, when any plants abounding in eſſential oil are diſtilled with a quantity of ſpirit of wine, the ſpirit brings over with it, a ſtrong flavour of the plant. Proof ſpirit is uſually employed in this operation, and the manner of diſtilling is altogether the ſame, as that made uſe of in diſtilling the ſimple water and eſſential oil.

The uſual direction in pharmacopœias for diſtilling theſe ſpirituous waters, as they are called, is to take a fine proof ſpirit in the proportion to the ingredients, which the preſcription appoints, and to draw off the quantity put into the ſtill; but to prevent the ſpirit from contracting an empyreumatic tincture from the burning of the ingredients, when they ſhould become dry; before the fire is kindled under the ſtill a quantity of water is added, which being left at the end of the diſtillation will be ſufficient to keep the ingredients from drying.

This method of drawing off a quantity equal to that of the proof ſpirit uſed, is the moſt commodious

modious for the apothecary, whose medicines must be all of the same goodness. But the distiller, who can make a diversity of price to different customers; when he has drawn off about two thirds of the spirit put on, carefully examines the spirit afterward as it runs from the still, and as soon as he perceives what runs begins to acquire a blueish, or perhaps a whitish tint, he removes, what is already come off, and collects, what runs farther, by itself. This has not so delicate a flavour as the first, and is what they call the faints. The first spirit thus reserved by itself is stronger than proof, and is reduced to the proof standard by the addition of pure water.

Their faints, when they have collected a sufficient quantity of them, are re-distilled by themselves.

Spirit of wine is also often used to draw tinctures from vegetables. It is particularly applied to extract the resinous parts from plants. Camphire it dissolves entire, very expeditiously.

The resin of jalap is extracted by spirit of wine. This is commonly performed by pouring rectified spirit on jalap root.

But this resin may be otherwise obtained. Pour upon jalap root powdered rectified spirit of

wine, and with a due heat draw a tincture, and boil the residue several times in water; after straining, draw off the spirit from the tincture till it begins to thicken; inspissate also the strained decoctions; then mix the two extracts, and with a gentle fire reduce them to the consistence of a pill.

This preparation has been so much preferred by the college of physicians for medicinal uses, that they have not given the foredescribed resin a place in their present pharmacopoeia.

Spirit of wine is also useful in preparing the extracts by water only of such vegetable substances, as abound in resinous parts; for though many of these parts will boil out along with the rest; yet these, by not uniting freely with the other parts, will cause the extract to crumble, and not unite into a uniform tenacious consistence as it ought to do. But a little spirit of wine then added brings the extract immediately into its due form.

By the power in spirit of wine dissolving oils, it is useful in rectifying volatile salt; for if a quantity of it be poured on the salt, and the salt be sublimed, the oil will unite with the spirit, and the salt ascend very pure.

It

It is the general doctrine, that some resinous bodies are so refractory, that they will not dissolve in spirit of wine, unless first digested with a lixivial salt. Myrrh is a subject usually proposed, as an instance of this. But myrrh will dissolve, as it were, entirely in boiling water, and a small part only will fall out of it, as it cools. This part unites with spirit of wine. If the water be evaporated, a gum is left, from which spirit of wine will take no tincture. Spirit of wine will take a tincture from myrrh without any separation of its parts, being previously made by water; and, as far as I could discover by experiment, will receive as much from myrrh, simply used, as when prepared with a lixivial salt.

Hoffman teaches, that if camphire be ground with salt of tartar, spirit of wine distilled from it will partake strongly of the flavour and taste of the camphire, without suffering any separation upon mixing with water, as happens in the simple solution of camphire in that spirit. This I have also found to be a mistake; and likewise, that there is no sensible difference in spirit of wine distilled from camphire with or without the salt.

If the highest rectified spirit of wine be poured on an equal quantity of a volatile alkaline

ſpirit perfectly free from any oil, and ſhook together, they will at once coagulate, eſpecially if the weather be cold. This is called offa alba and offa Helmontii. But this experiment muſt be omitted, till we come to conſider ſal ammoniac, whence we ſhall produce a volatile alkaline ſpirit more perfectly free from oilineſs, than what we can prepare at preſent.

A

COURSE of CHEMISTRY.

PART III.

Of FOSSILS.

LECTURE XII.

AFTER animal and vegetable ſubſtances, the next to be treated of are thoſe, which are dug out of the ground. Theſe in general are called foſſils. Such of them, as will melt in the fire, are diſtinguiſhed by the name of minerals, that of foſſils being moſt uſed to denote the reſt. We ſhall begin with the ſalts.

The foſſil or mineral ſalts are nitre or ſalt-petre, alum, borax, and vitriol; to which ſea-

ſalt

ſalt may be added, a ſalt of the ſame kind being alſo dug out of the ground, though uſually diſtinguiſhed from that extracted from ſea-water by the name of foſſil ſalt. If any of theſe are diſſolved in water, and then the water is evaporated to a certain degree, and upon this the water be ſet in a cool place, the ſalt will precipitate from the water, and gather together in cryſtal-like bodies of a regular ſhape, but which is different in each ſalt.

This operation is called the cryſtallization of the ſalts, and has been already conſidered.

The cryſtallizing of ſalts is the ſecureſt method of purifying them from all heterogeneities. By filtring the water, wherein they are diſſolved, all earthy foulneſs is ſeparated, and if different ſalts are diſſolved together in the ſame quantity of water, they ſeparate from each other in ſhooting.

Thus much in general of theſe ſalts. To proceed to particulars, alum, and moſt of the vitriols, if heated, emit a large portion of water: after this diſtilled with a ſtrong fire they yield an acid ſpirit, which is the ſame in either material. Sea-ſalt, and nitre are leſs humid than the others; but diſtilled yield alſo acid ſpirits differing from that, which is obtainable from the other ſalts, and alſo from each other. But in

order to raiſe the ſpirits from theſe two ſalts ſome kind of clay, bole, or other equivalent material, muſt be mixt with them: nitre requires three times its own weight, at leaſt, of ſuch a clay, and ſea-ſalt much more; alum and vitriol require no ſuch addition.

If either of the other ſalts were put to diſtillation alone, they would melt, and might at length be rendered ſo ſubtle, as to run through the veſſel, which contained them; but would never part with their ſpirit. Why theſe clays or boles procure the expulſion of theſe ſpirits, ſhall be explained preſently.

If borax be put to diſtil by itſelf, it ſwells greatly, as alum will do; but during that time emits nothing. At length that ſwelling ceaſes, and the ſalt after diſcharging a watry part melts down into a kind of glaſs; but is ſtill diſſolvible in water. If borax be diſtilled with a bolar earth, it ſends out a larger quantity of water impregnated very faintly with an alkaline quality. But this quality ſeems only to ariſe from the alkaline lixivium uſed in refining it.

Alum has never in practice been diſtilled for its ſpirit, becauſe vitriol, which affords the ſame, is a cheaper material. Vitriol is prepared for diſtillation by firſt evaporating its watry part in an earthen pan over an open fire. This ſalt

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contains so large a share of water, that with a small degree of heat the water contained in it will liquify the vitriol, causing it at first to flow like water: but when the humidity is evaporated, the salt becomes dry. This operation is called the calcination of vitriol. When the vitriol is thus dry, it becomes of a greyish white, and in the parts nearest the fire, red. The farther this calcination is pushed, the fitter it is rendered for distilling its spirit; because it should not clod together in the distilling vessel, and there is no danger, that the moderate heat used in calcination should deprive it of any part of its acid spirit.

But how far soever the calcination is continued, the spirit afterwards drawn from it will contain a watry part, which must be separated by a gentle distillation. What is thus drawn off will be acid, as well as that, which remains; and the rule, by which the distillation is regulated, is to continue it, till both the liquors appear clearly transparent, whereas the spirit after the first distillation, has a blackish hue. The spirit left in the retort is now said to be rectified, and to distinguish it from that which is drawn off, is usually, though very improperly, called oil of vitriol, it is the heaviest of any fluid, except quick-

quickſilver, being not much leſs than twice the weight of water.

Alum calcined in the ſame manner, as vitriol, exhales near as great a quantity of water; but then is reduced to a white friable powder, which by diſtillation affords the ſame ſpirit, as calcined vitriol, and alſo requires the like rectification.

If this water, which evaporates from alum, be collected by diſtillation, towards the latter end it acquires a ſulphureous ſmell; and the like happens in vitriol alſo.

The friable ſubſtance, into which alum calcines has a cauſtic quality from the acid ſpirit ſtill remained in it, and now undiluted with water.

But this powder will diſſolve in water, and by cryſtallization return to alum again. From calcined vitriol may alſo be extracted with water a ſalt, which is not diſpoſed to ſhoot; but muſt be obtained by firſt filtring the water from the vitriol, and then evaporating to dryneſs.

To expel the acid from vitriol or alum it is neceſſary to place the veſſel containing them over the fire in an incloſed furnace, that the flame may encompaſs it, beating on the top, as well as on the bottom and ſides: the ſluggiſhneſs of this vapour requires alſo, that the veſſel be ſo placed,

placed, as to give it an exit laterally. The furnace appropriated to this distillation is called the reverberatory furnace.

The spirits of sea-salt, and of nitre rise more freely, and therefore neither require so lateral an exit, nor altogether so strong a fire.

From these distillations it appears, that these salts are composed of an acid spirit, and a terrestrious part. These earths differ no less than the spirits. However these salts are not found in their respective forms, because the acid spirit of each is more disposed to join with those earths, than with any other. On the contrary, the acid of vitriol will fasten upon the earth, either of sea-salt or of nitre, if poured upon either of those salts, and dissolve the union between their earths, and the spirits, to which they were originally combined.

This affords a method of obtaining the acid spirits from sea-salt, and nitre with much less heat, than by the process before described with clay or bole: for when the acid of vitriol has been poured on either of these salts, a moderate heat will raise their acid spirits from them. These spirits fly off so readily upon the affusion of the spirit of vitriol, that the operation ought indispensably to be performed under a chimney, that the rising fumes may be carried

away

away from the operator; those from nitre especially might otherwise be attended with very fatal effects, scarce any fume being more destructive to the respiratory organs, and the life of animals, than that from nitre. If in the operation with sea-salt a portion of water is not added, the fume is so volatile, as scarce to be confined in the distillation.

In this method of preparing these spirits, the oil of vitriol joining itself with the earthy part of the salt, forms a new salt, which is found in the bottom of the retort. That, which is left in distilling spirit of salt, after it has been dissolved in water and crystallized, is used often as a gentle purge under the name of Glauber's sal mirabile. The cake left after the distillation of nitre being likewise dissolved and crystallized resembles tartarum vitriolatum, described hereafter and is usually sold under that name.

The same effect as the acid of vitriol has on sea-salt and nitre, the spirit of nitre also will have on sea-salt of dissolving the union between its earth and acid spirit. For some purposes in metallurgy a compound spirit made by mixing the acid spirits of nitre and of sea-salt together, is required. This spirit has obtained the name of aqua regia, given it from its power of dissolving gold, by those, who have been pleased to

style

ſtyle gold the king of metals. But to obtain this compound, it is not neceſſary to prepare the two ſpirits of nitre and of ſalt ſeparately; for if ſea-ſalt be put in ſubſtance into ſpirit of nitre, the ſpirit diſtilled off will bring along with it the ſpirit of the ſea-ſalt, and leave a portion of itſelf with the earthy part of that ſalt.

The power in the acid of vitriol here deſcribed makes vitriol itſelf a very commodious inſtrument for ſeparating the acid ſpirit from nitre or ſea-ſalt; for the ſalts being mixt with it and diſtilled, more acid ſpirit may be obtained from the ſame quantity of ſalt, than by mixing them with boles or clays.

The ſpirit of nitre thus diſtilled is uſually called aqua fortis. A certain quantity of vitriol is neceſſary to expel from the nitre all its ſpirit. The refiners take equal weights for their ſtrongeſt aqua fortis, but uſe Dantzic vitriol; the ſpirit could not be all diſengaged from the nitre without a greater quantity of ours; but then by the redundancy of the watry part in ſo large a ſhare of vitriol, the ſpirit would be weakened. But this may be remedied by calcining a part of the vitriol; though if all the vitriol ſhould be calcined, the ſpirit of the nitre, for want of a due quantity of water to receive it, would fly off in an aerial vapour and be loſt.

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The earths we before proposed for distilling these spirits operate in great measure upon the same principles: for those are fittest for the purpose that partake of the vitriolic acid.

The refiners distinguish their strongest aqua fortis from a weaker sort made by them, by the name of double aqua fortis, the weaker being called single aqua fortis. This they prepare by adding to the nitre a greater quantity of vitriol in the proportion of seven to five, without any other effect from this increase than diluting the spirit with a greater quantity of water.

The single aqua fortis, converted into aqua regia by the addition of salt, is used by dyers in the dying of scarlet. What farther preparation the spirit undergoes, before they apply it to that purpose, and why they so prepare it, shall be shewn hereafter. At present I shall only take notice, that the tincture of cochineal in water is of a dark colour, but by any acid a precipitation is made, and the colour becomes a scarlet: but the forementioned spirit makes it of the brightest colour.

(*Here the experiment.*)

The spirit of salt, and of nitre prepared with oil of vitriol, as above described, smoke incessantly, when exposed to the air. It is remarkable, that these fumes are heavier than the air,

though they rise so freely; for they soon tend downward. They are raised from the spirit, not by their natural volatility, but by the air's imbibing them: so that the air is properly a menstruum to these spirits, and, as it were, dissolves them, and disperses them about itself. The action is between the watry part of the air, and the acid of these spirits. Oil of vitriol is too ponderous to fume; therefore on the contrary, that spirit imbibes the humidity of the air so much, that if it stand any time in an open vessel, it increases considerably in quantity.

As the acid of these spirits unites itself with the watry vapours of the air; so on the other hand, the air sustains the vapours raised in it by its acid acting on them. The suspension of vapours in the air not having been considered in this light, philosophers have been at a great loss to account, how the heat of the sun should so rarify the water, as to make some particles of it lighter than air, which they have always supposed necessary to be done, that the vapours might be suspended. But it is evident, that the air will even imbibe water without much heat: a wet cloth in the coldest night short of freezing will gradually dry. The warmth of the air contributes indeed much to the elevation and suspension of vapours, both because water is a vo-

latile

latile ſubſtance, and raiſed with a ſmall heat, and as heat increaſes the action of all menſtruums. But, though heat alone will raiſe vapours from water, without the action of the air upon them they ſoon fall again.

When the vapours have diffuſed themſelves high in the air, by the cold of thoſe upper regions they are condenſed into viſible clouds. In winter the coldneſs of the lower air will condenſe them, and cauſe fogs; a fog being only a cloud flying contiguous to the ground. But in the warmeſt weather the air high above us has but little heat. The heat, we have here upon the earth from the ſun, is two fold. One is the degree of heat reſulting from our particular diſtance from that globe of heat, as well as of light. The heat we receive from this cauſe is that, which we compare with the like heat other planets receive from the ſun; and is the ſame to us by night as by day. The other cauſe of heat from the ſun is the action of its rays upon the bodies, they ſhine on: and different bodies receive very different degrees of heat from thence. Metals, and other the moſt denſe bodies, conceive, by lying in the ſun, the greateſt heat: but bodies of leſs denſity are leſs heated by the ſame degree of ſun-ſhine. The air, being a

very rare body, will receive but ſmall heat from the ſun's rays paſſing through it. The heat of the lower air is reflected from the earth. The great heat of the lower air above the upper is that, which cauſes hail. The upper air by its cold has frozen the vapour into ſnow, which in falling is ſo far melted, as to unite together into a body of ice, which ſnow always does, when it begins to melt. Hence it is, that hail falls in warmer weather, than ſnow does, and hailſtones are frequently found with ſnow in the middle.

I ſhall now ſay ſomething of the method, how theſe ſalts are obtained originally.

Sea-ſalt is got by evaporating the ſea-water, which in warm countries is done by the heat of the ſun. Thus bay-ſalt is made. In hot ſummers bay-ſalt is ſometimes made in England. But in this country we ſupply the want of ſun by actual fires. In the ſalt-works near Newcaſtle, where coals are of little coſt, they boil away the water directly taken out of the ſea. In other places they ſpread the water into ſhallow ſquare receptacles dug in the ground, which they call pans, where the water in part evaporates firſt; and then they finiſh the work by fire.

The

The ſame kind of ſalt is alſo dug out of the earth, and is cleanſed from the impurities mixt with it, by diſſolving it in water.

There are alſo ſalt ſprings, whoſe water boiled away leaves juſt the ſame kind of ſalt. We have ſeveral of theſe in England. In theſe the water is much more ſtrongly impregnated with ſalt than the water of the ſea. In boiling away theſe waters to collect the ſalt, they free them from impurities by mixing with them blood or the whites of eggs. Blood, in particular the ſerous part, and the whites of eggs coagulate by heat: ſtirred therefore with the boiling liquor, while they coagulate, they intangle the impurities, and riſe with them up to the top. Where ſalt is made from ſea-water, and the water has ſtood in pans a great length of time to evaporate; its foulneſs ſubſides, ſo that it is not neceſſary to clarify it.

I ſaid above, that this ſalt cryſtallizes, while the water is hot. The grains are rendered larger by this artifice. Some unctuous or reſinous ſubſtance (ſuppoſe roſin, or what is at preſent particularly in eſteem, gum-ſanders) mixt with butter is in a ſmall quantity dipt into the liquor, when it is boiled ſo far away, that the ſalt would ſoon be left a dry cake, and then the fire is checkt, that the liquor may juſt ceaſe

from boiling. The oily ſubſtance ſpreads itſelf over the ſurface of the liquor, and contributes to ſeparate an acrid ſaline ſubſtance contained in the liquor, which would obſtruct the cryſtallization of the ſalt. It has been lately diſcovered, that a very minute quantity of alum will perform this ſtill more effectually. The ſalt granualtes at the top of the liquor, and falls to the bottom. This is taken out with ladles, and laid in troughs perforated, that it may drain. The liquor, that drains from the ſalt, contains another ſalt, that will alſo cryſtallize, but not while the liquor is hot. But this liquor being left open to the air, this ſalt ſeparates out of it, and concretes into large irregular lumps, which being diſſolved again divides into the forementioned acrid, ſaline ſubſtance, which does not ſhoot into cryſtals, but only ſubſides, and another ſalt, which cryſtallizes over it, thoſe two being ſeparated by a thin cruſt of common ſalt. This cryſtallized ſalt reſembles that contained in the purging ſprings. And this is the ſalt, which is every where ſold under the name of Epſom ſalt.

All the nitre, which has long been uſed with us, comes from India, where it is made from the earth of a ſoil near the city of Patna abounding with it, much after the ſame manner, in

which

which it was formerly made here, and is ſtill in ſeveral countries in Europe, from earth expoſed long to the air, but kept covered from the ſun and rain, boiling this earth in water to extract the ſalt, and filtring the water through aſhes to free it from an oilineſs, which comes along with the ſalt from the earth.

Alum is dug out of particular mines, and is contained in a ſtone, which is firſt to be calcined, then ſteept in water, by which the alum is extracted. A water alſo ſometimes iſſues from the ſides of the mine, which yields pure alum, by evaporating with the ſun's heat only. But to the alum extracted by water from the calcined ſtones, ſo much of the ſtony part ſtill adheres, that it is neceſſary to ſeparate it, that the alum may cryſtallize. This is performed with kelp and ſtale urine. How theſe materials accompliſh this, will appear at our next meeting. Kelp is the aſhes of the kali, and often hangs about oyſter-barrells.

Vitriol is of three kinds, green, blue and white. They agree in the ſame acid ſpirit. The green is moſt uſed, and this kind is uſually called copperas. Theſe vitriols differ chiefly in a ſmall portion of metal, which is in them. The blue vitriol has copper in it, the white, the

mineral called zink, and the green, iron, of which indeed they all in ſome meaſure partake.

The green vitriol is made here in England, and is freer from any other metal, but iron, than any of the foreign. It is drawn from ſtones found on the ſea-ſhore in places, where the ſoft earth is waſhed by the ſea. In ſuch places, as the earth is continually worn away by the ſurges, theſe ſtones are uncovered. Theſe ſtones muſt lie ſome years expoſed to the ſun and rain; till at length a liquor runs from them, which is boiled up with iron. The iron is corroded and conſumed with the liquor. The liquor being boiled away to a proper degree, and ſet in coolers, the copperas cryſtallizes to the bottom and ſides of the cooler. The iron furniſhes the copperas with ſome of its metallic part, but not with all of it: for copperas may be made from this liquor without iron, though not ſo plentifully; and ſometimes copperas is found to be ſhot from the liquor before boiling, as it lyes in the ſun.

The liquor is boiled in leaden veſſels; becauſe it will corrode iron and copper.

Theſe ſtones contain ſulphur or brimſtone in them, alſo iron. Hereafter we ſhall ſee, that common brimſtone contains the ſame acid ſpirit,

as is produced from vitriol. While theſe ſtones lye in the open air, they undergo a kind of fermentation, whereby the acid ſpirit is ſet looſe from the other parts of the ſulphur. This ſpirit thus diſengaged corrodes the iron, and produces vitriol. That this ſpirit will convert iron into a ſalt reſembling vitriol, we ſhall ſee hereafter. As the acid ſpirit in theſe ſtones, is more than what ſuffices for the iron in them, iron added in the boiling of the liquor increaſes the quantity of the vitriol.

In Saxony near ſome of the copper-mines they find an earth and ſtone, which ſteept in boiling water, as ſoon as dug up, impregnates the water with copperas, which is obtained only by boiling away the water, till the copperas will ſhoot from it.

At the ſame place white vitriol is made by ſteeping in cold water a particular kind of lead ore, which contains zink or ſpelter, and boiling down the water, till the vitriol will ſhoot from it. And then the vitriol is farther whitened, and ſome part of its humidity evaporated by another operation upon it, which they call calcining it. This is performed, by putting it into a copper veſſel, and with a proper heat melting the vitriol and boiling it for ſome time, after-

wards

wards it is removed into wooden troughs, where it is ſtirred about, till cold.

If theſe ſtones abound in copper, blue vitriol will be produced. Of theſe we have none in England.

In Germany blue vitriol is prepared by mixing together two minerals, one of which furniſhes the vitriolic ſpirit, the other being a poor kind of copper ore. They are beaten to powder, and waſhed from the light earth mixed with them, then calcined together for ſome time, and afterwards boiled in water.

In ſome countries copperas ſtones abound much more with ſulphur than ours. Common brimſtone is frequently melted out of ſuch ſtones.

Borax is obtained by cryſtallization from a mineral called tincal; after the tincal has been duely purged from an unctuous part, wherewith it is charged. This ſalt alſo ſhoots from the liquor while hot, and beſt, if the veſſel be covered.

LECTURE XIII.

IN the mineral ſalts, I have had under examination, the acid principle appears in fuller force, than it does in vegetable ſubjects.

Wherein the acid ſpirits differ from each other is difficult to ſay. Poſſibly they all agree in one common acid principle, and that their difference ariſes from ſome adventitious matter, to which the acid is joined. Whoever could prove this, or could certainly ſhew the contrary, would make an important diſcovery in chemiſtry. In the mean time we may obſerve, that there are but four acid ſpirits known in nature; the vegetable acid, (which appears in its greateſt purity in vinegar,) the ſpirits of nitre, of ſea-ſalt and of vitriol.

By the diſtillations deſcribed in the preceding lecture, it appears of all theſe ſalts, except borax, that they are compounded of an acid ſpirit, which is expelled from them, and of an alkaline earthy part, wherewith the acid was united. By this union the acid taſte is loſt, and another produced; inſomuch that both the acid and alkaline qualities diſappear, and ſome third quality,

lity, differing from either, results from their union.

The experiment may be made thus. The acid spirit is to be poured by degrees on a solution of some alkaline salt in water, or on an alkaline earth in powder. At the first affusion a strong effervesence arises; and as soon as that has ceased, more of the acid is to be poured on, and the operation repeated from time to time, till no farther effervescence is observed. Care is to be used, that the solution be poured on no longer, than till the liquors just balance each other. Then, if this liquor be duly evaporated, a salt will shoot from it.

When the experiment is made with spirit of nitre, and a fixt alkaline salt, the salt obtained resembles nitre so much, as scarce to be distinguished from it: it seems to be the very same salt.

The salt thus produced from the spirit of sea-salt shoots into the same form, as sea-salt itself; but has not the same taste. Here the salt produced in part resembles the original salt, whence the spirit was drawn, but not so perfectly as in the former case. The earthy part therefore of nitre seems to be the same, as that of fixt alkaline salt, which is a vegetable earth. The earthy part of sea-salt is something different.

When

When the acid spirit of alum, and that called oil of vitriol, is poured in like manner on a fixt alkaline salt, the salt produced differs yet more from the original salt, whence the acid was extracted. This is most commonly made with oil of vitriol and salt of tartar, and is called tartarum vitriolatum.

(*Here mix ol. vitriol. with sal tartar. for tart. vitriolat.*)

If these experiments are made with a volatile alkali instead of a fixt, a saline body in some degree volatile is produced.

If spirit of salt be poured gradually upon any animal volatile spirit, as upon spirit of hartshorn, of urine or the like, it produces a salt like that called sal ammoniac, so named from the temple of Jupiter Ammon, or at least from the sands of the neighbouring desart, being conceived to have been originally produced from the urine of the camels passing through that desart by its mixing with a saline soil. It is at present made in Egypt, but by what process has not yet been perfectly known to us.

If this salt be put in a low glass vessel with a wide mouth or in a retort, and set in sand, by a strong degree of fire gradually raised upon it, the salt will wholly sublime, except a few earthy dregs left at the bottom.

Though

Though this is an operation of little value, for the salt is better purified by solution in water. Yet if a portion of a fixt alkaline salt be added to it, it will rise very white, otherwise not.

But by mixing the alkaline salt in a due proportion, the sal ammoniac may be decompounded, and the principles of which it consists made very manifest; for the alkaline salt will draw to itself and retain an acid similar to that of sea salt, and disengage a volatile alkaline salt perfectly resembling that obtained from animal substances, which by this means will ascend alone. If water be added to the mixture it comes over in the form of a spirit, and is called the spirit of sal ammoniac.

What remains at the bottom is no other than the spirit of sea-salt joined with the fixt salt made use of.

The volatile salt from sal ammoniac is freer from oil than any, we have hitherto produced from other substances. It may be impregnated with the flavour of vegetable oils in this manner. Put any aromatics of an agreeable odour into spirit of wine together with some sal ammoniac, and a quantity of fixt alkaline salt: then distil the whole in a gentle heat. The fixt alkali separates from the sal ammoniac its volatile salt, while the spirit of wine extracts the odoriferous

oils

oils from the other ingredients. Thus the ſpirit comes over impregnated with thoſe oils and volatile ſalt united. This preparation is called ſpiritus ſalis volatilis oleoſi. And may be more compendiouſly made by diſtilling ſpiritus ſalis ammoniaci dulcis from aromatic eſſential oils.

The acid ſpirits of all the ſalts, except nitre, have a ſtronger tendency to unite with the alkaline ſalts, than with their own, or any other earth. The vegetable acid in tartar ferments with an alkaline ſalt, and depoſits its own earth. A ſolution of an alkaline ſalt poured on a ſolution of ſea-ſalt, alum, or vitriol makes a precipitation from them.

In nitre, if pure, the experiment does not ſucceed, whoſe earthy part is the ſame with that of the fixt alkaline ſalt, as appears both by the experiment above deſcribed of regenerating nitre from its ſpirit, and a fixt alkaline ſalt, and alſo from the production of a fixt alkaline ſalt from nitre by a proceſs preſently to be deſcribed of burning out its acid ſpirit.

Though either of the alkaline ſalts produce the effects now mentioned, yet there is a difference in their acting on theſe ſpirits; for the ſpirits have a ſtronger tendency to unite with the fixt alkali, than with the volatile.

Upon

Upon this principle it is, that the volatile salt is recovered again out of the sal ammoniac by the help of a fixt alkaline salt.

The power in alkalis now mentioned to make a precipitation from alum is the reason, why they are used in the manufacturing that salt. Without their help the alum would contain too much of this stony part, which they precipitate.

This property of alum has made it useful for preparing several pigments.

Mr. Boyle has in good measure described the method. And Antonio Neri, in his art of making glass, is still more particular in his account of them. He calls these pigments lacs.

A lixivium or lie of moderate strength being made with a fixt salt (if you please its force may be increased with a little lime.) With this lixivium is to be extracted in a gentle heat the tincture of any flowers, woods, or the like, whose colours will not be spoiled by the fixt salt. This tincture being strained off, is to be set over a fire and boiled, and as much alum thrown into it, as it will dissolve. Straightway the stony part of the alum, precipitated by the fixt salt, will separate from the liquor, tinged with the colour of the tincture.

The Prussian blue, a colour in great reputation, is made after the like manner, though the pro-

process is a little more complex. It is this. They first mix a quantity of blood dried with an equal weight of fixt salt, and calcine them together in a covered crucible. The heat at first should be gentle, afterwards raised. The matter during the calcination flames and glows. The higher the calcination is carried, the deeper will the colour be. When the calcination is finished, they break the matter in a mortar, and boil it some time in water: one pint of water is enough for each ounce of the blood used. Then for each ounce of blood one quarter of an ounce of English vitriol calcined, till it is white, and half an ounce of alum, or more, are to be dissolved together in the same quantity of boiling water, the two liquors are to be filtred, then mixt together boiling hot. Immediately ensues a great ebullition and green colour. The mixture is poured from one vessel to another as long as the ebullition continues. After this, being strained through a cloth, a pigment is left behind.

When this is well washed to free it from the loose salts, it becomes of a beautiful blue colour; or if it prove less perfect, a little spirit of salt readily corrects the defect.

Upon the same principles alum is useful in dying. All the dyers of woollen, except those

who dye in scarlet, boil their cloth with alum, before they put them into the tinged liquor, that is to give it its colour; and with all their colours, except cochineal, they mix either some fixt salt, as pearl-ashes or pot-ashes, or else putrid urine. These alkalis extract the acid of the alum adhering to the cloth, leaving the stony part, which I have already shewn, that those substances extract from alum; and this stony part of the alum, is a body proper to receive the dye. In order to fix this stony part of the alum firmly to the cloth, they find it useful to add tartar to the alum. They boil their cloth before dying in water, wherein both alum and tartar are together dissolved after the rate of about thirty pounds of tartar to eighty of alum.

I mentioned just now, that nitre might be converted into an alkaline salt, by burning out its acid spirit; this may be performed after the following manner.

If nitre be melted in a crucible and pieces of charcoal thrown upon it, it will flash and blaze out vehemently. This operation may be repeated so long, till no farther flashing will follow the throwing in of the coals. Then what remains of the nitre, is a fixt salt, and may be separated from the ashes of the coal by steeping them in water, and proceeding according to the

method before taught for extracting the fixt salt from vegetable ashes

This process is called the detonation of nitre.

The like denotation happens, though not so vehement, when nitre and tartar are mixt together in equal portions, and thrown gradually into a red-hot crucible. And by this means a strong alkaline salt is instantly produced.

Nitre exposed alone to the greatest heat will never take fire, but melt like other salts. But if added to any inflammable substances, it very highly increases their inflammability: for this fulmination succeeds, whatever inflammable substance is thrown upon the nitre.

The spirit of nitre, drawn as before described with oil of vitriol, will burst out into a flame, when poured on half its quantity of any oil very free from acidity; such as the ponderous oils of the eastern spices, and animal oils.

It also appears farther, that the concurrence of an inflammable substance is necessary toward the production of fixt alkaline salt; for when the acid of the nitre is expelled by simple distillation, the earthy part only of the nitre is left; but here a part of the acid seems to be retained, and so united with a portion of the sulphur of the coals, that it cannot be separated from the salt in any other form, than that of an aerial vapour.

pour. And this effect is produced by distilling any fixt alkaline salt mixt with thrice its weight of bone-ashes or the like simple earth. We shall hereafter see other methods of producing air from a union of acid and sulphur.

The experiment succeeds best, when the distillation is finished with a moderate fire.

This is a very instructive experiment. In the first place it shews, to what part of the nitre we must ascribe its power of increasing the inflammability of bodies. In the next place this experiment shews us, to what principles the phosphori owe their sudden inflammability. The phosphorus from urine dissolves in the air into an acid liquor; therefore is compounded of an acid and inflammable substance united together. The phosphorus with alum to be described at our next meeting, has the acid spirit of the alum joined to an inflammable substance.

We may also learn from hence, on what principles the air procures the inflammability of bodies. That the air contains in it an acid, its effect on metals makes manifest, as we shall see hereafter; nay that the acid of the air nearer resembles that of nitre, than any other known to us. And by this experiment it appears probable, that inflammable bodies are set on fire, by the acid of the air acting on the inflammable

sub-

ſubſtance in the body. As a certain degree of heat is required to excite this action, ſo, where the body already contains a large portion of an acid ſpirit, that ſpirit, when the body is heated, aſſiſts the air in its operation; ſo that a leſs heat is neceſſary to fire thoſe bodies than others. Hence it is that not only the phoſphori take fire ſooner than other bodies; but common brimſtone (which we ſhall find hereafter to be compounded of an inflammable unctuous ſubſtance and an acid ſpirit) catches fire with leſs heat than ſimple oil.

The reaſon, why our experiment ſcarce ſucceeds with oils, that have any acidity in them, is this. The oils are cold, wherewith the experiment is made, therefore the acidity within them is not put in action to contribute any thing toward their heat. And the action between the acid ſpirit poured on, and the oil is much ſtronger, where the oil is wholly deſtitute of acidity, than in oils, that have already ſome portion of acid; juſt as we ſee in the ſaline liquors, which ferment, the fermentation is ſtronger upon the firſt affuſion than afterwards. Common brimſtone being at full impregnated with acid, will not be acted on at all either by the acid of nitre or any other.

But by the affusion of every acid spirit upon any oil, a degree of heat will be produced, though it be not great enough to set the oil on fire. The forementioned spirit of nitre will set even oil of turpentine on fire, if its action be assisted by making the oil first a little warm.

The acid spirits will also excite a great heat and fermentation with spirit of wine. Mixing thus these acid spirits with the vinous one is called dulcifying them. The spirits of salt and of nitre are commonly thus dulcified, that they may be taken safely into the stomach, as medicines.

After they are mixt, it is usual to distil them; by this means the acid spirits are certain to be impregnated with their due quantity of the vinous spirit.

When oil of vitriol is mixt with spirit of wine, the mixture upon distillation, parts into different liquors, though not into those whereof it is compounded. Mr. Boyle describes this process at large. The first liquor, that ascends with a very gentle heat, is a light spirit more inflammable, if possible, than spirit of wine itself, and differs from spirit of wine in its smell. Moreover, if this process is conducted with proper circumstances, the liquor produced, though by its great levity and volatility it retains the name of spirit, is in reality an oil; for it will not unite with

with water, and is the ſpiritus vini ætherius introduced among us under this name by a German chemiſt, Frobenius. This inflammable ſpirit is followed by others. At laſt a black pitchy ſubſtance, but taſteleſs, and not inflammable, is left behind.

This property in vinous ſpirits, of mixing with and dulcifying acid ones, is that, which gives them the power, we formerly mentioned, of checking fermentation in vinous liquors. Dulcified ſpirit of nitre will not ferment with lixivial ſalts.

The acid ſpirits in ſome meaſure coagulate all oils, they are mixt with. The ſpirit of nitre will not incorporate wholly with olive oil; but though the oil remains on the top of it, it will receive ſuch an alteration from the ſpirit, as to become of the conſiſtence of butter. Oil of vitriol mixt with eſſential oils unites with them into the ſolid conſiſtence of a pill.

From this effect of acids on oleaginous ſubſtances, we may form a probable conjecture concerning the cauſe of that ſurprizing property of the ſerum of the blood, and of the white of eggs, peculiar to the animal juices, that of being coagulated in its whole ſubſtance by a ſmall heat: for the ſtrong acids have the ſame effect upon them without any heat, and alkaline ſpirits

obstruct this effect of heat, as Mr. Boyle has discovered. It is therefore reasonable to suppose the blood charged with so much of an acid principle as will produce, by the means of heat to augment the power of the acid, this effect. Probably the greater consistence of the fat of animals above that of the oils of vegetables is owing to the like coagulating principle.

Camphire is liquified by spirit of nitre. Oil of vitriol dissolves it wholly, and holds it down so perfectly, that no smell can be perceived. Water poured into it raises the camphire, and then it exhibits its usual smell.

Here we conclude our examination of salts. Mineral sulphurs are next to be considered.

LEC-

LECTURE XIV.

AFTER the ſalts, we proceed in the next place to conſider ſulphurs; the right underſtanding of which is very neceſſary in the treatment of metals; metallic ores being generally a compoſition of the metallic part, and a ſulphur united with it; and the art of refining conſiſts very much in diſſolving the ſulphureous part, ſo that it may ſeparate from the other.

The nature of theſe ſulphurs will be underſtood, by what we are going to exhibit on brimſtone, the moſt common of them.

There are two ſpecies, under which may be ranked the ſubſtances generally attending metallic ores. They are alſo found where no metal is near. Theſe two are ſpars, and what in ſeveral parts of England are called mundicks. Spars are cryſtalline bodies, formed in angular ſhapes, as ſalts ſhoot. Mundicks are ſulphureous ſubſtances, by the Greeks called pyrites, and by the Arabians marcaſites. Their general character is to have a ſulphureous ſmell and to ſtrike fire with iron or ſteel.

Theſe all contain a conſiderable quantity of ſulphur, that may be obtained from them by

ſublimation. Some ſo abound with brimſtone, that it melts out with a ſmall heat. This is one way common brimſtone is made.

It is a compound body conſiſting of an inflammable part, an acid ſpirit, like that drawn from alum and vitriol, and an earth charged with an inconſiderable portion of metal. But the acid ſpirit is not to be ſeparated from it, as from ſalts, by diſtillation; for thus treated it ſublimes into flowers, and by this ſublimation is purified. To ſeparate the acid ſpirit, the ordinary method has been to ſet the brimſtone on fire under a glaſs of a proper form to receive the fume: for by this means, while the inflammable part is conſumed by burning, the acid ſpirit uniting with the moiſture of the air condenſes upon the glaſs, and trickles down by the ſides of it into a large diſh placed to receive it, the earthy part being left after the ſulphur will burn no longer.

This glaſs uſed to be formed in the ſhape of a bell; but, whereas the rim of a bell turns outward, it has been found moſt convenient to turn the rim of this glaſs rather inward, and alſo to draw the top of the bell out into a long ſtem left open to give paſſage for the ſmoke, which otherwiſe muſt come out from under the bell, and be very offenſive to the operator.

However

However this glaſs, though altered a little in its form, goes ſtill by the name of the ſulphur bell, and the ſpirit thus made is called ſpiritus ſulphuris per campanam.

Water impregnated with the fume of ſulphur, has been uſually called gas ſulphuris, but in the preſent pharmacopœia aqua ſulphurata, this water receives that part of the ſulphur, to which its inflammability is owing, accompanied with a ſmall ſhare of acidity. The power of ſulphur, in reſtraining the fermentation of vinous liquors, which have been fumigated with it, ſeems chiefly owing to this inflammable part; for ſpirit of wine, as we have obſerved before, is indued with the ſame power.

The inflammability of ſulphur has given occaſion to chemiſts, in their philoſophy to call the inflammable part of all ſubſtances their ſulphur. The character of foſſile ſulphur is to melt with heat, though in the cold it be hard and brittle, ſoon to take fire, and burn with a flame, and to be indiſſolvible in water or in any acid ſpirit. The ſubſtances found in the earth, which agree with this deſcription in all but being hard in the cold, are called bitumina.

In moſt of the ſubjects we have hitherto examined, we have made uſe of the ſimple application of heat to decompound them. In ſome

few

few instances that method has proved ineffectual. The coal resulting from the distillation either of animal or vegetable substances, could not be deprived of the principle, to which it owes its blackness, and its power of burning, by mere heat. Sal Ammoniac, another compound substance, will not divide by heat alone, but the whole sublimes together. The like happens to sulphur, which, heated in a close vessel, sublimes intire, and this operation is usually practised upon sulphur to purify it. Sulphur thus sublimed is called the flowers of sulphur. For sale it is thus sublimed. The sulphur is thrown into iron pots set in a furnace and heated. The pots have a moveable cover, which is taken off to throw in the sulphur, and presently stopt down again. An iron pipe opens from each pot near the top, into a room big enough for a man to enter. Into this room the sulphur flies out of the pots upon its subliming, and settles upon the floor, and sides of the room. When the operation is finished, the flowers of the sulphur are swept together with a broom.

Several preparations are made with sulphur by dissolving it with proper menstruums. Neither water nor any acid spirit will operate upon it. But oils and the fixt alkaline salt of vegetables

bles do diſſolve it. Flowers of ſulphur boiled with four times as much oil in an open veſſel, will unite by the evaporation of the watry part of the oil into a uniform ſubſtance of a conſiſtence, whence it receives the name of balſamum ſulphuris. This is moſt uſually prepared either with oil olive, oil of turpentine, or oil of aniſeeds.

Fixt alkaline ſalt melted with ſulphur makes it diſſolvible in water. Sulphur thus melted with a fixt alkali is called hepar ſulphuris. Sulphur may alſo be diſſolved in water by boiling it in a ſolution of a fixt alkaline ſalt; for thus the alkaline ſalt will diſſolve the ſulphur, and give a tincture to the water therewith. Upon this tincture if any acid ſpirit be poured, it preſently becomes turbid, and a powder ſubſides; which after frequent waſhing by ſtirring it with a large quantity of water, and as ſoon as it ſubſides, pouring the water from it, is called lac ſulphuris, and magiſterium ſulphuris. Melted it turns yellows, and reaſſumes the ordinary appearance of brimſtone. This proceſs is alſo performed with lime, as we ſhall ſhew at our next meeting, and is the only method, in which the preparation is, in the way of buſineſs, made.

Sulphur

Sulphur thrown upon nitre in fusion inflames violently with the nitre, and causes an explosion. If this be done only, till the nitre flows clear like water; the nitre then poured out is called sal prunellæ. If as much sulphur as nitre be used, the result is, what is called sal polycrestus, a medicine much celebrated by writers, but at present scarce in use here. It differs not essentially from tartarum vitriolatum, the acid of the sulphur having dispossessed the acid of the nitre from its earth, and taken place in its room. In sal prunellæ the alteration, the nitre undergoes, is so small, that with us it is little regarded, there being no manifest reason for preferring it to nitre purified by crystallization only.

This sudden fulmination of nitre with brimstone is the principle, upon which the action of gun-powder is founded. That powder is only a mixture of nitre, and brimstone with charcoal dust. The use of the charcoal is to set the composition suddenly on fire.

There is a great difference in authors with regard to the proportion of the ingredients, some advise to take equal parts of charcoal and brimstone; others direct twice as much of the coal. They differ also in the quantity of nitre.

The

The powder is much improved by well mixing the materials. This is of more consequence than an exact observance of the proportions. The powder made here in England, for the government, is composed of 75 pounds of nitre with 15 of charcoal and 10 of brimstone. For the use of merchants the powder has less nitre and more charcoal. The corning it is also an advantage towards its sudden taking fire. This requires a double sieve. The holes of the uppermost being as large, as the corns are intended to be, the under smaller. The powder, so moist as to form a kind of paste, being put into the upper sieve with a piece of wood, that may break it to pieces, while the sieve works. The under sieve lets the dust fall away, but retains the corns. In practice a treble sieve is generally used with holes gradually smaller. The corns stopt at the second sieve are used in great guns, and therefore called cannon-powder; the smaller corns stopt by the third sieve make the pistol-powder used in all small guns. The workmen have a contrivance to make the corns of gunpowder look shining, which they call glazing it. This is done by shaking the powder in a barrel, that has held black lead.

There is another mixture called pulvis fulminans, made by putting a fixt alkaline salt to the

nitre and brimstone instead of charcoal, which explodes perhaps with more force than gun-powder itself; but this will not suddenly fire. It must be gradually heated over coals.

The proportions for this mixture are three parts of nitre, two parts of the alkaline salt, and one of brimstone.

The sudden accension of gunpowder is owing to the power, we have before remarked to be in nitre of increasing the inflammability of combustible substances. And the vehement explosion arises from the large quantity of air, into which great part of the gun-powder is converted upon its accension. This has been found to be the case by firing gun-powder in a close vessel; for here a great quantity of air is seen to be at once produced.

The inflaming power of nitre is the cause, that gun-powder is the only combustible substance, that has yet been experimented upon, which will fire in a vacuum. Even the phosphorus of urine, which in the open air takes fire with so very little heat, and burns so fiercely, as we have seen, cannot be enkindled in a vacuum. But the nitre in gunpowder supplies in some measure the place of air.

However the presence of the air is so far necessary to the sudden accension peculiar to gun-

powder,

powder, that if it be not formed into corns, or if in dust lie loose, whereby the air may be plentifully diffused through it, but being reduced to fine dust, be rammed down close; it then will not explode at once, but burn upon its surface only.

For this reason in all fireworks, where the powder is to burn gradually, it is beat into dust.

This power in nitre to promote the inflammability of other substances, makes it a necessary ingredient in all fireworks, in those, where no explosion is desired, as well as in those, wherein an explosion is made.

The principal of artificial fireworks made for diversion are rockets. Upon these the construction of most of the rest depends. And as the effects of rockets depend upon the subject now before us, it may not, perhaps, be amiss to describe briefly their structure.

A rocket is a hollow cylinder usually made of paper, of a thickness equal to about one-sixth of its diameter within, and fill'd with gunpowder of some like composition. If a rocket be made of great bigness, intended for a signal in war or such like use, its case may be made of a more solid material.

Near one end the case of the rocket is drawn in, till its diameter be reduced to one-half of

the whole internal diameter. This place is usually called the choke. The most approved length of the case from the choke is about six times its internal diameter, to be filled with gunpowder; if the rocket be small, beat into fine dust, and rammed in with as even strokes as can be, that the powder be uniformly compressed. In great rockets the charge is usually a little weakened by adding to the gun-powder a small portion of charcoal and of sulphur.

To the end of the rocket is added a cylindrical cavity not above half the length of the rocket from its choke in height, and of such a diameter, that, together with the materials put into it, it may not exceed the weight of the rest of the rocket. These materials, besides some corn-powder to burst the case, consist of some composition, that may give the appearance of stars, a shower of fire, or the like.

These fiery showers may be made of saw-dust boiled in water strongly impregnated with nitre, and while wet rolled among gunpowder in dust; or by gunpowder mixt with melted brimstone, and when cold grosly beaten.

These stars are a mixture of gunpowder, nitre, sulphur, antimony, camphire, and the like combustible materials moistened with a solution of some gum, thereby to form pellets of a convenient

venient ſize. Theſe pellets are to be covered over with thread well ſoak'd in a ſtrong ſolution of nitre and while wet roll'd in gunpowder. To charge the rocket with larger balls, any of the foreſaid ingredients (whereof nitre in a ſufficient quantity muſt always be one) may be mixt with turpentine, melted pitch or roſin, and tow ſteept in it. This way larger balls may be formed, which ſhould be covered over with thread prepared as juſt now deſcribed.

It is neceſſary for giving the rocket a ſufficient degree of motion, that the powder within the rocket be bored with a tapering cavity from the choke. At the choke this cavity muſt be as wide as the choke itſelf, at the farther end it need not be more than one-half of that width. The length of this bore muſt be but one inner diameter of the rocket ſhort of the whole height, to which the rocket is rammed. The uſe of this bore is to increaſe the ſurface, that takes fire at once; that a greater body of fire may iſſue out of the mouth of the rocket. For from the vehemence, with which the fire iſſues out, the rocket receives its motion. Rockets are uſed in all fire-works, that have motion, except ſuch as are thrown into the air after the manner of bombs. When the rocket is deſigned to mount upwards, a ſtick eight or nine times the length

of the rocket is tyed to it, sufficient to poize the rocket at an inch or two from its mouth.

Nitre furnishes other compositions useful in war besides gun-powder, upon the same principles.

If nitre be mixt with pitch, rosin, turpentine, sulphur and such combustible materials, and tow be steept in it; fire-balls formed of this tow will serve to illuminate any place desired. If the tow be gradually wound into a ball, and from time to time first dipt in this mixture, and then roll'd in gun-powder, the ball will burn yet fiercer, and such a ball will not only be useful in giving light, but therewith an enemy may be annoyed, in particular any edifice may be fired with it.

Bombs and grenados, which are only iron shells filled with gun-powder, are to be light, before they are delivered; but the powder must not take fire, till they arrive at the place designed. For this reason a hollow piece of wood resembling in shape the fosset of a tap is drove into them, and the hollow of this wood is fill'd with a combustible material, that will burn slowly. This is usually made of pulverized gun-powder with an additional quantity of some of the other ingredients, to alter the proportion

they

they have in the gun-powder. This matter is rammed hard into the cavity.

It is from the analysis of sulphur, that we must learn the cause of the great combustibility of the phosphori. The phosphorus from urine I have before observed to contain, besides its inflammable part, an acid spirit: That invented by the late famous Homberg is a union of the acid spirit contained in alum with an inflammable part from animals or vegetables.

This phosphorus thus compounded of alum, and some animal or vegetable substance, takes fire the most readily of any thing yet known: for being thrown out of the bottle, which contains it, into the open air, it fires immediately and burns, what it lies upon, without any assistance by rubbing, or by any warmth applied.

No mineral substance mixt with allum will make this phosphorus, nor any salt but allum.

The most ready method of preparing this phosphorus is to put the alum mixt with the other material into a crucible, and heat the mixture gradually, till it grows red hot and burns with a small blue flame; breaking the mixture from time to time during the operation, that it may not concrete into one mass: then it must be taken immediately out of the crucible, and put into a vial made hot enough

not to be broke by the heat of the matter put into it.

Arſenic is uſually conſidered by the chemiſts along with ſulphurs. But improperly. I ſhall conſider it among the imperfect metals. Orpiment, frequently confounded by writers with a factitious ſubſtance called yellow arſenic, is a mineral properly to be called ſulphureous.

But to conclude let me farther ſay ſomething of that ambiguous ſubſtance amber, which has at length been diſcovered to be a foſſil.

It was indeed moſt uſually found floating on the ſea. But it has lately been dug out of the earth in Pruſſia; where in digging they found firſt a ſtratum, which had the appearance of old wood, and was combuſtible; immediately under this was a layer of copperas ſtones. Theſe lay upon a bed of ſand, out of which they got pieces of amber in great plenty.

In diſtillation it yields an acid ſpirit, a finer and a groſſer oil; alſo a volatile ſalt in a ſolid form. This ſalt is not an alkali; but contains an acid ſpirit ſo looſely adhering to its earth, that it will ferment with alkalis even without heat, which ſcarce any other ſalt will do. The acid of this ſalt is the ſame, with that of the ſpirit, which riſes with it in the diſtillation.

At

At the end of the diſtillation of amber there is left at the bottom of the retort a black pitchy ſubſtance.

The ſalt of amber comes from the ſubject, as other volatile ſalts do, foul with oil. This ſalt is not ſo volatile, as to riſe with the heat of boiling water. And the uſual way of purging it from its oil, is to boil it in the ſpirit, or in ſimple water, and ſet it by to ſhoot.

LECTURE XV.

Of STONES.

HITHERTO the greateſt part of our operations, upon the ſubjects, we have handled, has been to analize them, and reduce them into the principles, whereof they are compounded. But the preſent ſubjects are ſo ſimple in their ſtructure, that our chief purpoſe will be to ſhew the effects, they produce, when compounded with other ſubſtances.

We ſhall here conſider ſtones. Some of theſe are tranſparent, others not. Of the tranſparent, thoſe, which exhibit the moſt beautiful colours and luſtre, are called gems. Gems are rivalled in tranſparency by glaſs, but are preferrable to it in degree of hardneſs; by which means they take a much finer poliſh. They are often imitated by coloured glaſs, but are eaſily diſtinguiſhed by the weight. Precious ſtones being much heavier than glaſs. They have even the greateſt ſpecific gravity of any ſtones. The heavieſt of theſe is the diamond. But this ſtone cannot poſſibly be counterfeited to any perfection; be-

because its beauty is not owing to any colour; but only to its eminent lustre, which arises from its great refractive power. By this quality it reflects much more light than any other transparent body whatever; those bodies in general reflecting most light, which have the greatest refractive power. By this quality also it exhibits, when its surface is formed into a variety of different planes, a greater diversity of colours, and those much more vivid, than can be exhibited in like manner by any other transparent substance. But the consideration of gems has no direct relation to our present undertaking. With regard to stones of the transparent kind we shall only here observe, that sand, which is a heap of very minute stones, and flints calcined in the fire, till they can be powdered, will melt with any vegetable fixt salt into glass. But glass does not melt as salts and metals do. They flow thin like water; glass melts into a tenacious consistence. Hence it is, that glass upon its first melting appears full of small blebs or bubbles. These arise from the air, that is copiously lodged among the materials, they being powders. And as the glass melts into a tenacious consistence, the air in these bubbles extricates itself but slowly. Length of fire expels it, and renders the glass uniformly transparent.

In glaſs-houſes the fire is kept up night and day without intermiſſion, as long as the building will endure, and as their pots work out, they fill them up again with freſh materials. In the bottle glaſs-houſes their pots are worked out in one day, and freſh materials melted in them in the night.

This tenacious conſiſtence of melted glaſs, is the reaſon, that it is wrought otherwiſe than melted metals are. Melted metals are always caſt into a mold. But glaſs is taken up by putting into it the end of an iron pipe red-hot. A portion of glaſs will ſtick to the pipe; and the pipe being hollow the glaſs is blown up by the breath of the workman, and ſhaped with iron tools, and by rolling it on a marble. If the glaſs cools and grows hard, before it has received the deſired ſhape, it is put from time to time, while on the pipe, into the furnace, and held there, till it grows ſoft enough to be wrought on.

Iron is the only metal to which glaſs adheres; the reaſon of which ſhall be aſſigned hereafter, The fire of the furnace is not kept altogether up to ſo intenſe a heat, while the glaſs is wrought, as while it is melting.

Common red ſand and the aſhes of wood or ſtraw melted together, make the green glaſs uſed for

for bottles. This glaſs is the leaſt tractable of any, and does not melt ſoft enough to be moulded ſo freely, as finer glaſs, into any ſhape. Though the materials for all the other kinds of glaſs, except that called flint-glaſs, differ from this bottle-glaſs only in the whiteneſs of the ſand, and the purity of the aſhes. In the bottle-glaſs red ſand, and the earthy part of the aſhes, as well as the fixt ſalt are mixt together; for glaſs more tranſparent aſhes in ſome degree purified are uſed. In the fineſt Venetian glaſs, which was once in great eſteem before the invention of flint glaſs, they uſed fixt ſalt entirely purified from the earthy part of the aſhes.

Flint-glaſs has lead in its compoſition, and we ſhall more fully deſcribe it, when we come to ſpeak of the glaſs of lead. It is called flint-glaſs, becauſe it was firſt made with calcined flints; but now they uſe only fine white ſand, which is found to have as good an effect, and requires no previous calcination neceſſary in flints, that they might be pulverized, in order to their being mixt with the other ingredients. The fineſt Venetian glaſs was alſo made with calcined flints.

The proportion for this fineſt Venetian glaſs is ſet down by Antonio Neri to be thirteen parts of the fixt ſalt to twenty of the powdered flint,

that

that is about two parts of the salt to three of the flints. In the making all glass it is usual to mix a great quantity of old glass with the fresh materials, as this addition much facilitates the melting. In bottle-glass, they put in old glass and fresh materials in equal proportion.

All glass is disposed to have more or less of a greenish hue: this is taken off from the fine glass by adding to it a small portion of a stone found in Italy called manganese. Writers in Latin call it magnesia. Agricola mistakes it for the magnet or load-stone.

Flint-glass does not acquire this green hue. Therefore no manganese is used in it.

Some plants, which grow on the sea-shore, contain in their ashes, besides the alkaline salt, which they have in common with others, another salt, which will not unite with sand, as the alkaline salt does; but, when salt is made with any of these ashes, it flows melted on the top, and is taken off with ladles, before the glass is wrought, this is called sandiver.

One use of calcining stones is to fit them for glass, though now this practice be laid aside for the reason before mentioned. Another effect from calcining many stones is a power they thereby receive of attracting water very strongly.

Ala-

Alabaster fresh calcined attracts water so strongly, when wet with it, that it unites again into a hard and firm stone. This is the preparation called plaister of Paris. At length the calcined stone by gradually imbibing the moisture of the air is in some measure saturated with water, and then the action between it and the water becomes faint, and it will not harden, as it does when newly calcined.

Stones are in general to be divided into two classes; such as melt with fixt salt into glass, all which will strike fire; and such as will not vitrify, and these burn into lime. The earthy part of animal and vegetable substances resembles this latter kind of stones.

Lime, which is made either by calcining chalk, or by the calcination of particular stones called from the use of them, lime-stones, attracts water so strongly, as in action to excite a great heat.

The effect of the phosphorus made with alum seems in part to arise from the same principles; the stony part of the alum calcining into so subtle a lime as to heat enough by the mere moisture of the air, to set fire to the oily or sulphureous part of the other ingredient, whose inflammability is heightened by the acid spirit of the alum, which joining with the oil of the other

in-

ingredient composes a very inflammable sulphur. From the materials of the phosphorus mixt I have sublimed yellow flowers like those of brimstone.

Lime is of a nature analogous to fixt alkaline salts, but more exalted in its force. It does not intirely dissolve in water, as the salts do; but only communicates some of its subtle parts to it. Hence is produced a very valuable remedy called aqua calcis, described in the London dispensatory.

Again lime is made use of to increase the caustic quality of the fixt alkaline salts. This it does by its powerful attracting humidity. It is by this power of attracting all moisture, that the fixt alkaline salt itself is a caustic. It acts not on a dead body. But in a living one, where the humours are fluid; by drawing strongly all moisture out of the fibres, it dries them up with a quickness of action, resembling the effect of an actual fire; this when assisted with lime, they perform very strongly; alone their power is more languid.

The caustic usually called lapis infernalis is made by evaporating the soap-boilers ley, till it will coagulate, when cold, into a brittle substance; but care must be taken, that the ley be not boiled further than is necessary for this purpose.

The

The heat may be continued, till it is reduced to a dry ſalt.

This preparation muſt be kept in a glaſs well ſtopt, it being greatly diſpoſed to liquify by the air. This readineſs to liquify creates an inconvenience in the uſe of this cauſtic, by rendering it difficult to confine it to the limits, wherein its operation is deſired: for this reaſon it has given place in uſe to another cauſtic not ſo ſubject to this imperfection, which is prepared by forming a paſte with a very ſtrong ley and lime a little but not much ſlacked.

As lime bears a reſemblance in its nature to the fixt alkaline ſalts; ſo its action on ſal ammoniac is much the ſame with the action of an alkaline ſalt upon that ſubſtance; for being mixt with it, and diſtilled by the like proceſs as with a fixt alkaline ſalt, a volatile ſpirit is here alſo produced; but one that is much more acrid and penetrating, than when the alkaline ſalt is made uſe of.

If ſal ammoniac be mixt with fine chalk or whiting, a volatile ſalt will be raiſed in a ſolid form. This proceſs requires a ſtrong fire, the preceding one is performed with a gentle heat.

When lime and ſal ammoniac are mixt together, the volatile vapour aſcends and ſtrikes the noſe immediately; but when uncalcined chalk

is mixt with the salt, no such effect follows; that the volatile part may be separated, a strength of fire, which may give the chalk some degree of calcination is requisite. But where perfect lime is used, the active parts of the salt are so divested of the grosser earth, that no salt in a solid form can be obtained.

Lime seems to have a similar effect also on fixt alkaline salts; for in the preparation of the lapis infernalis, the quantity of the production falls considerably short of the salt, from which it is prepared.

Some have scrupled to call these spirits, thus drawn with lime, alkalis, because they do not make so visible an effervescence with acids, as those do, which are drawn with fixt salt. But if the fixt salt itself be highly calcined, the spirits drawn with it will have no more visible fermentation, than those have, which are drawn with lime.

Equal parts of quick-lime, sal ammoniac and sulphur being mixt together yield a spirit, which whenever open to the air emits a fume without ceasing, which is extreme subtle and penetrating.

Orpiment, which I observed at our last meeting to belong to the class of sulphurs, infused a little while in hot water, with double its quantity

tity of lime, impregnates the liquor with the most penetrating fume known.

Lime alſo diſſolves oils very powerfully; for this reaſon it is uſed in making ſoap to facilitate the uniting of the oil with the alkaline ſalt. The common ſoft ſoap has a mixture both of oil and tallow. In preparing it the ſoap-boilers firſt make a ley by pouring in water upon layers of pot-aſhes and lime warm from the kiln ſtrewed in a ſhallow pit interchangeably. They take care that the ley be not too ſtrongly charged with the ſalt. This they judge of by the weight of the liquor. With this ley they firſt boil the tallow; as ſoon as theſe boil up together, they add the oil, and immediately damp the fire, that the mixture may ſtand in digeſtion three or four hours, in which time the oil, tallow, and ley become united into one uniform ſubſtance: and this by boiling they gradually bring to the common conſiſtence of ſoap. When this ſoap is firſt made, it appears uniform; but in about a week's time, the tallow ſeparates from the oil into thoſe white grains, we ſee in common ſoap.

Soap thus made would look yellow, but by a mixture of indico added at the end of the boiling it is turned green, that being the colour,

which refults from the mixture of yellow and blue.

Oil will not join thus completely with a ley made from any of thofe afhes, which I obferved before to contain a falt, that does not incorporate with the glafs made from fuch afhes. But however the oil by repeated or long continued boiling with fuch a ley will gradually imbibe from it its alkaline falt, and be converted into a foap, which, when cold, concretes into a folid confiftence.

Hard foap may alfo be made with a ley, wherewith oil will perfectly unite. For this purpofe common falt is made ufe of. When oil or tallow has been united with the ley, after a little boiling falt is thrown in upon it, which readily diffolving in water, but not in the oil or tallow, draws the water in great meafure out, fo that the oil or tallow united with the falt of the ley fwims on the top.

Water impregnated with lime is made ufe of for refining fugar upon the fame principle of its diffolving oils. Coarfe fugar being boiled in lime-water perfectly diffolves in it, the grofs oily part, as well as the fweet part, which conftitutes the fugar. When the whole is by this means reduced to a uniform fyrup of a proper confiftence,

ence, it is ſet by in a heat ſufficient to keep the oily part fluid, that the ſugar may ſeparate from the ſyrup by a kind of chryſtallization, as ſalts ſhoot in water, that is charged with them to a certain degree.

To render this ſeparation more effectual moiſt clay is ſpread over the ſugar, when the ſugar begins to cryſtallize, that the ſugar may gradually draw in the moiſture from the clay, and the oily part by that means be more effectually expelled: for ſugar unites itſelf with water much more freely than with oil; ſo that when water is preſent, it will draw that in with force enough to expel the oil.

When the ſugar is brought near to a perfect fineneſs, it will unite entirely with water without the help of lime; therefore in preparing double refined ſugar lime is not uſed.

Lime ſeems alſo to have ſome effect on the acid part of the juice of the ſugar-cane; for it is uſed in the firſt making of ſugar, lime in ſubſtance being put into the juice before boiling; but in a very ſmall quantity, ſcarce above the meaſure of half a pint of powdered lime to three hundred gallons of juice, which ſhall make as many pounds of ſugar. Here the lime ſeems to produce at once the ſame effect as time will occaſion without the aſſiſtance of any art. The

ſugar we ſee adhering to raiſins candied is only their juice concreted into that form. In the richeſt kind of ſugar-canes the juice, which exſudes from accidental fiſſures in them, will concrete into ſugar by the heat of the ſun. Perhaps this was the only ſugar known to the ancients.

(Here a ſugar-mold ſhewn.)

Lime is alſo made uſe of to diſſolve ſulphur in the preparation of what has been called lac ſulphuris, but in our preſent pharmacopœia ſulphur precipitatum. A quantity of ſulphur being boiled with three times its quantity of quicklime, till the ſulphur is diſſolved, and the decoction filtred; upon the affuſion of any acid ſpirit, the liquor turns to a milky whiteneſs, and depoſits a powder, which is to be waſhed frequently in warm water, till it has loſt all its acrimony.

Calcined chalk impregnated with the acid ſpirit of nitre will produce a kind of phoſphorus not always ſhining in the dark, as the phoſphorus from urine does; but immediately after it has been expoſed to the light of the day or the beams of the ſun it ſhines, if it be forthwith removed into a dark place. This is the phoſphorus of Balduinus. There is a ſtone found near Bononia in Italy, which being

ing calcined only, exhibits the ſame phæno-menon.

The moſt convenient method of preparing the phoſphorus of Balduinus is this.

Firſt let good chalk lime be powdered, and put by degrees into the ſtrongeſt ſpirit of nitre, that can be prepared after Glauber's method, till ſuch times as the ſpirit is ſaturated, and all ef-ferveſcence ceaſes.

This compound being diluted with a quan-tity of water, and filtred; the liquor upon eva-poration ſhews, that the acid ſpirit has convert-ed a conſiderable part of the chalk into a ſalt. From this ſalt the phoſphorus is thus to be pre-pared.

Provide a ſhallow earthen diſh made of an earth, that will endure the fire; place it in a fire, till it is red hot. Then throw into it of the fore-mentioned ſubſtance reduced to pow-der by little and little. As ſoon as ever a quantity is thrown in, it boils up; and the ſucceſs of the proceſs depends upon throwing in a freſh quantity, before the boiling up of that laſt thrown in is quite over. As ſoon as the laſt parcel is thrown in and melted, the diſh is to be removed from the fire, and placed, before it is cold, under a glaſs, which

must be well cemented down to keep out the air.

The most commodious method of placing the dish in the fire is under a muffle in an essay-furnace.

A

COURSE of CHEMISTRY.

PART IV.

METALLURGY.

LECTURE XVI.

OF the substances, that are dug out of the earth, such of them, as melt in the fire, we have observed to be called minerals, the rest being only named fossils.

Minerals that afford metallic substances are usually called ores: these are the next subject of our inquiry. Metallic ores are of two kinds; for some afford a perfect metal, from others can be separated only a metallic body, not having the perfect form of a metal. The cha-

racters, by which metals are distinguished from other bodies, are being fusible and malleable. That is, whatever substance melts with heat, and ductile under the hammer, when cold, is properly called a metal.

The metallic bodies, to which these characters agree, are lead, tin, iron, copper, silver, and gold. Of these tin is the lightest in weight, and gold the heaviest; the next to tin in specific gravity is iron, then copper, after this silver, then lead almost of the same weight with silver, and gold greatly exceeds the weight of any of the rest. The imperfect metals are quicksilver, bismuth, spelter, and a metallic substance separable from the mineral called antimony. Quicksilver differs from those properly called metals, by its perpetual fluidity; the rest, which are solid, by the want of malleability, though they have an external appearance, and weight resembling a true metal, and are fusible in the fire.

In order to understand the true intention in each part of the processes, by which metals are separated from their ores, it is necessary to have some knowledge of the nature of the metals. This is best obtained by calcining them.

It is well known, that metals, not only when melted, but when heated in the fire are soon

covered

covered over with droſs. Lead or tin melted, their ſurface at firſt appears of a ſhining brightneſs, but is preſently ſullied with a dim ſkin. If this be removed, it is ſoon ſucceeded by another. Iron or copper, when made red-hot, caſt off brittle ſcales. The metals kept long in the fire will by degrees waſte thus wholly away into droſs. This is called calcining them, and the friable ſubſtance, into which they are thus reduced, the calx of the metal. This calx is ſpecifically lighter than the metal. There is beſides an acceſſion of new matter. Lead when calcined into that red powder called minium and red lead, gains about a twentieth part in weight.

Lead and tin eaſily melt, and being ſtirred about, while they remain melted, ſoon are reduced into powder; and this powder by being longer in the fire will change from its firſt colour, till in tin it becomes white, in lead red, whence minium or red lead ſo called.

The proceſs, whereby minium is made, is this. The lead is placed in a reverberatory furnace, where with a due degree of heat and ſtirring, it is reduced into a greyiſh droſs. The particles of this droſs often contain in them ſome lead uncalcined. To ſeparate the calcined part this droſs is ground in a mill with water. During the grinding the water carries

ries out of the mill all the fine droſs. The reſt which is imperfectly calcined ſubſiding. This reſidue is calcined and ground afreſh; till no more groſs parts ſubſide. The fine droſs thus obtained, is placed again in the furnace, and a proper heat raiſed upon it, whereby it gradually changes its colour, till it becomes red. The reverberatory furnace here uſed is ſo contrived, that the heat may be equal on every part of the matter. Therefore here two long fires are made uſe of, one on each ſide of the matter.

(Here ſhew the red-lead furnace.)

Iron and copper are beſt reduced to a calx by being kept for a length of time red-hot: for thus ſcales will continually caſt off from them. If the metal be reduced into very ſmall parts, before it be expoſed to the fire, theſe ſcales will be generated quicker than otherwiſe, the ſurface of the metal being increaſed.

Silver and gold bear the fire to that degree, as to ſuffer no change by the longeſt continuance in the hotteſt fires we can make by any fewel. However theſe bodies are not abſolutely indeſtructible by intenſe heat; for burning-glaſſes have been made to collect the ſun-beams ſo ſtrongly, as readily to reduce both theſe metals into a calx. Monſ. Homberg proſecuted this experiment very fully with a glaſs of the

late

late famous Duke of Orleans. Several years ago we had here in England a metalline concave brought hither by the maker, Monſ. Villette, which produced a degree of heat ſtill more intenſe than the burning-glaſs, which Homberg made uſe of; but the ſun's rays being in that collected by refraction, and the rays deſcending upon the ſubject to be examined, the ſubject could be more commodiouſly kept in the focus for a length of time, than can be done in reflecting metals, where the rays aſcending upwards will be intercepted by any body, whereon the ſubject examined can be laid. In theſe metals therefore the ſubject can only be kept in the focus, till it is melted; and it was ſurprizing to ſee how ſoon the mirror of Monſ. Villette melted down the hardeſt bodies, and thoſe, which indure the longeſt in our moſt intenſe fires. Monſ. Homberg by his glaſs found, that gold, when expoſed to a heat ſtrong enough, was affected like other metals, and burnt like the reſt to a calx.

But as gold is not to be moved at all by our fires any farther than to be melted, ſo quickſilver with a moderate heat evaporates. But if quickſilver be put into a glaſs, and expoſed long, to a leſs heat than what will evaporate it; in length of time it will be reduced to a red

powder,

powder, which has usually been called Mercurius præcipitatus per se; but is now by the college stiled Mercurius calcinatus.

The calx of lead is called by different names according to the degree of calcination it has undergone. When calcined till it is become red, it is called minium or red lead, as has been already observed. The calx of lead acquires this colour, not by the violence, but long continuance of the fire.

When lead is burnt off from silver or gold in order to separate those metals from it, (the practice of which will be illustrated hereafter) it suffers a greater heat, but not so long continued. After this calcination it is called litharge. It does not here acquire so bright a colour, but litharge will receive this colour and become minium by a long calcination.

Litharge has been distinguished into two kinds, litharge of gold and litharge of silver, as if the metal, from which the lead was burnt, made a difference in the litharge; whereas the litharge is simply lead calcined, unless when it is mixt with a small quantity of what other base metal, may have rendered the silver and gold impure. However litharge is seen of two colours, which arises only from this. As it falls from the furnace, it concretes into larger lumps, the

the outſide of which to ſome depth in cooling becomes of a pale colour, the inner part being red.

Lead and tin calcined together in the proportion of two parts of lead to one of tin makes a white powder called by workmen putty, and is uſed in poliſhing metals. This is not the putty of the glaziers. That is whiting with or without a little white lead wrought into a paſte with linſeed oil.

Lead, when calcined, will diſſolve in oils, as is ſeen in making the plaiſters, which have calcined lead in their compoſition; ſuch as the common plaiſters, which have gone uſually under the name of the diachylon, emplaſtrum e minio, &c.

Iron, calcined till it becomes red, was the crocus martis aſtringens of the London pharmacopœia. But ſcarce two authors agree in their account of the preparation of this medicine. There is another crocus of ſteel called aperiens, which we ſhall mention hereafter. This alſo has almoſt as many proceſſes for its preparation, as there are authors, who deſcribe it. Nay what in ſome authors is called crocus aperiens, is called by others aſtringens. Nor is it eaſy to aſſign any great difference between them in their operation however prepared: they are all the

calx

calx of iron. Our chemists at present sell the colcothar of vitriol for both.

The calx of lead by a strong heat will again melt, and become a reddish kind of glass. This glass will incorporate with sand. If three parts of litharge be melted with one part of white sand, it makes what is called vitrum saturni, or glass of lead, and is a preparation useful in treating silver and gold ores.

That called flint-glass is a composition of fine white sand, nitre, and lead. They do not put lead in its metallic form into their pots with the other ingredients, because upon its first melting it would sink to the bottom and corrode the pot, so as to eat holes in it. They therefore use either red lead (the preparation of which I have just now described) or white lead, the process for making which will be explained hereafter, or both together.

Nitre and sand without any farther addition will make a fine transparent glass; but it is not durable: it will soon be full of little flaws, called by the workmen crizling. The addition of lead preserves the glass from that defect. When this glass was first made in England the proportions observed were one part of lead, two of nitre, and about three and an half of sand. But this glass after a course of years became subject

to the forementioned defect. More lead is now employed; though if too much be used, it gives the glass a blackish hue; and likewise arsenic in a small quantity is added to the composition.

The yellow and red glazing of earthen ware is litharge spread over the vessel already burnt, and then melted upon it into glass, by a second burning: the colour is yellow or red according to the earth it is burnt upon. The litharge is spread upon the vessel by this means. The litharge is ground with water, till it is reduced to extreme fine parts, and mixt with the water to some consistence; into this mixture they dip the vessel. The water soon soaks into the burnt earth, and leaves the litharge evenly spread over it.

The black glazing is performed in the same manner with that kind of lead ore, which breaks in large flakes, and is on this account called potters ore.

(Here the model of the potters furnace.)

White glazing is composed of three parts lead and one of tin calcined together. Then melted into an opake kind of glass with sand and the ashes of the sea-weed called kelp, this glass being ground with water and laid on, as the other glazings are.

Thus

Thus our fires easily vitrify the dross or calx of lead; but are scarce strong enough to melt perfectly the calx of any other metal. Our fires will also vitrify the metallic part of antimony. If the mineral be roasted with a gentle fire, at first it smokes; when this smoke ceases, if it be melted, there separates a metallic part: (other methods of obtaining this metallic part will be shewn hereafter,) but here if the roasting be longer continued with a fire gradually increased, and at length the mineral is melted for a due time, a glass is produced, which has been used in medicine, and is a strong emetic.

However the burning-glass before mentioned would not only turn gold into a calx, but even melt that calx into glass.

The experiments that were made with that glass upon metals, illustrate greatly the nature of those bodies.

When gold or silver were held in the very focus of the glass, after melting they were dissipated in small grains, which being collected, appeared to be minute globules of metal nothing altered, just as we shall find quicksilver to be dispersed by our fires. At a small distance from this place of the intensest heat the metal smoked much, and a powder soon gathered upon the substance of the metal, which in gold

would

would melt into a little ſpeck of glaſs, and run off from the metal, leaving the ſurface of the metal bright, which would ſoon be covered again with freſh calx, and that melt again into another ſpeck of glaſs as before. The calx produced upon the ſurface of ſilver would not melt, but lay ſpread over the metal in the form of a fine duſt, gradually increaſing. If the ſilver had been melted with antimony, there would appear a vitrification.

If the ſilver or gold were held ſtill a little farther from the focus; it only ſmoked and waſted very ſlowly without calcining at all.

In all theſe experiments the metal was held to the glaſs lying on a piece of charcoal.

If any of the other four metals lead, tin, copper, or iron, were held to the focus of the glaſs upon a teſt made of bone-aſhes, they ſoon calcined. Lead, quickly after its calcining, vitrified. Tin would ſcarce vitrify at all. Copper vitrified completely. Iron almoſt, but the ſubſtance it lay upon melting at the ſame time hindered the proſecuting of the experiment to ſo perfect a vitrification, as was effected in copper. All theſe calxes, even when vitrified, upon being laid upon a piece of charcoal in the heat of the focus ſoon returned again into metal. All theſe metals if laid upon charcoal in the heat of the fo-

cus ſmokt, and waſted very faſt, but would not vitrify at all, except iron, which ſometimes would begin to vitrify, when the coal was ſo burnt, as to be turned to mere aſhes to a good depth under the iron.

Iron exhibited ſeveral particular appearances. Before it melted a black pitchy ſubſtance fried out of it. This the experimenters call the ſulphureous part of the metal. But it lay upon the metal without burning. If we conſider the manner, in which iron is produced from its ore, I think we may form a better opinion of this ſubſtance. In making malleable iron the laſt remains of the droſs, or cinder, as the workmen call it, are hammered out. This droſs is black, as they deſcribe the ſubſtance, that fried out of the iron before the burning-glaſs, and is more fuſible than the metal. Without doubt therefore this ſubſtance was a little remains of this droſs left in the iron.

As ſoon as the body of the iron melted upon the charcoal, it ſputtered very much, and would waſte all away in fiery ſparks, except in the forementioned caſe, when a large bed of mere aſhes gathered under it; but if ever it ceaſed from ſparkling by that means, by ſhaking the coal, and thereby removing thoſe aſhes, the ſparkling would return again.

Iron

Iron upon the teſt did not ſputter at all, except it had firſt been melted upon charcoal; then upon a teſt it would ſputter all away.

If the iron, after its being vitrified, were laid upon a piece of charcoal in the focus of the glaſs, it continued quiet for ſome time; but at length it would begin to ſputter. Then being removed it appeared no other than melted iron.

Thus we ſee the inflammable body, charcoal, reſtored to metals their form, after their malleability and other proper characteriſtics had been deſtroyed by calcination; as if the coal ſupplied the metal again with what, the great heat of the glaſs had deprived them of.

In the ſame manner litharge and the calx of tin heated red-hot in a furnace, ſoon return again into their reſpective metal upon being mixt with charcoal, tartar, ſea-coal or any other inflammable ſubſtance. But the heat, wherein this operation is performed, muſt be greater, than what would melt thoſe metals. Even out of flint-glaſs the lead may again be recovered by this means, if the glaſs be mixed with a quantity of a fixt alkaline ſalt to render it more fluid.

The ſcales of copper alſo, though not ſo eaſily reduced as litharge, yet the operation may be

effected with a ſtrong fire by the addition of an inflammable ſubſtance.

The ſcales of iron are not eaſily reduced by our fires. It has been attempted at the furnaces, where iron is ſmelted, without ſucceſs. This is owing to the difficulty, wherewith iron melts. For in the other metals a greater heat is required to reduce the calx, than what would melt the metal. The fore-mentioned burning-glaſs would not give heat enough to reduce the calxes of gold and ſilver.

All theſe effects ſhew, that there is in metals an inflammable ſubſtance; the imperfect metal called ſpelter flames in the fire upon being melted. But though this appearance is ſeen in no metal, yet iron, when brought to a very intenſe heat, will not be cooled by blowing air upon it, but be brightened by it, as if farther heated by the blaſt after the manner of inflammable ſubſtances; alſo as nitre has been ſhewn to increaſe the inflammability of burning bodies very much, ſo the two lighteſt metals tin and iron, by being mixt with nitre, will ſend out a very bright flame.

Farther, though nitre will not cauſe lead to flame, yet it will ſuddenly produce in it the ſame effect as a ſtrong action of the fire: for if nitre be melted by a ſtrong fire, till it is red-

hot,

hot, a lump of lead thrown into it will ſuddenly be calcined by it.

But there is alſo another effect in the calcination of metals, which deſerves our enquiry: this is whence their calxes ſhould receive the additional weight they acquire; this being an effect not peculiar to red lead only. I think we may ſafely anſwer, that it is from the air. I had occaſion to take notice toward the beginning of theſe lectures of the ſtrong action, there is between inflammable ſubſtances and the air. When any body burns under a cloſe veſſel, till it is extinguiſhed, a conſiderable quantity of air is found to have loſt its elaſticity. This effect, compared with the preſent obſervation upon the calcining of metals, points out to us pretty plainly, whence the calxes of metals receive their additional weight, and what becomes of that portion of air, which ſeems to be conſumed by burning bodies. Without doubt, while the air by acting on the inflammable ſubſtance either in metals or other bodies expels it from them, it unites itſelf (in part at leaſt) to the remains of the body.

When red lead is reduced again into lead, it not only loſes all the increaſe, it has acquired, but likewiſe falls ſhort of the original quantity, ſhewing how much of the lead has fumed away in the calcination.

In calcining the metals care is always taken to have a free acceſs of the air to them. Hence it is, that in calcining quickſilver a pipe is inſerted into the containing-glaſs open at the bottom by a ſmall orifice, to preſerve a communication with the external air.

However, to render this matter ſtill clearer, it may be proper to conſider diſtinctly this queſtion, whether metals are reduced to the form of a calx, only by this new matter added, joining with the metallic particles, or whether they do not alſo loſe ſomething from themſelves? and, when metals are recovered from their calxes, whether it is effected by the inflammable ſubſtance put to them ſupplying them with ſomething the fire has robbed them of, or only by aſſiſting the fire in ſeparating the adventitious matter joined to the metallic particles?

It is evident, that all the adventitious matter gained upon calcination is diſlodged again upon the reduction of the metal. And, that the metal alſo receives ſomething from the ſubſtance joined with it, is, I think, manifeſt from the experiments above related.

The four metals lead, tin, copper, and iron, while lying on charcoal, would not calcine, excepting iron only in one circumſtance, where it was in the ſame caſe, as if it had not laid upon

a coal, but upon a ſubſtance not inflammable. Now in this caſe the calcination could be hindered no otherwiſe, than by the coal's ſupplying the metal with ſomething, which the heat took from it. In iron it is ſtill more manifeſt than in the reſt, that the metal imbibed ſomething from the coal, from that faculty of ſputtering, which it acquired by being melted on it; for it would afterwards ſputter, though removed upon a teſt. After it had been calcined, being laid upon a piece of charcoal the iron lay quiet for ſome time; but at length would begin to ſputter; and then was become iron again. Silver and gold calcined even upon charcoal in a certain degree of heat; but with a leſs heat they would not calcine, but waſte in fume, as the other metals did. When they calcined, I ſuppoſe, the charcoal could not ſupply them faſt enough, with what that great heat waſted.

What metals received from the charcoal, appears to be the principle, to which it owes its inflammability; for the coal burnt to aſhes faſter under one than under another. Iron conſumed it faſter than the reſt, as by the ſputtering of it, it appears to have imbibed more freely than the reſt.

Hence upon the whole we may conclude, that metals may be analized into two different ſubſtances;

ſtances; one whereon the body and ſubſtance of the metal depends, the other to which is owing the metallic form. This laſt appears to be that principle common to all inflammable bodies, to which they owe their power of burning, and therefore is in all metals the ſame; but the other muſt be different to conſtitute the diſtinct ſpecific qualities of each metal. Theſe two are the ſulphur and mercury of the ancient adepts.

LECTURE XVII.

HAVING thus discovered the constituent parts of metals, before we proceed to the operations on their ores, it will be requisite to shew the action of acid spirits, and salts upon them; for such substances are mixed with them in the ore.

And these acids may be considered in a two-fold respect, either when joined with water, and constituting an acid spirit; or when united with terrestrial substances, as in solid salts.

Now I shall consider the acid spirits.

By two of these all metals may be dissolved. Spirit of nitre alone will dissolve silver, copper, iron, lead, and quicksilver, and by the addition of spirit of salt the other two metals gold and tin.

This mixture of the spirits of nitre and of sea-salt, called aqua regia, dissolves all the metals except silver; and spirit of sea-salt alone dissolves all but gold and tin.

In the action of acid spirits upon metals and metallic bodies there are three remarkable differences to be observed. Sometimes the acid spirit

ſpirit ſo acts upon the metal, as to receive it into itſelf, that they become together one fluid body, and, if any quantity of water be added to the ſpirit thus impregnated, the metal ſtill remains ſuſpended, and is diffuſed throughout the water, as it was before in the ſpirit. Of this kind is the ſolution of ſilver, copper, quickſilver and other metals in ſpirit of nitre. In ſome inſtances the metal is only corroded to powder, and not joined with the ſpirit. This is the caſe of tin with ſpirit of nitre. There is likewiſe a third circumſtance, where the metal is received into the fluid, but it will not join with an addition of water. Upon the affuſion of water a precipitation is made. This is ſeen in tin, that has been diſſolved to ſaturation in aqua regia.

In the firſt caſe the acid of the ſpirit by uniting with the metal has converted it into a true ſalt. If the ſpirit by the help of heat has taken up a large quantity of the metal; the metal will ſhoot, when the ſpirit is become cold, after the manner of a ſalt. Theſe cryſtals diſſolve in water like ſalts. By a force of fire they gradually part with ſo much of their ſpirit, till they become indiſſolvible in water; which is alſo the caſe of other ſalts. Their becoming indiſſolvible by loſing a part of the adhering acid, ſhews the dif-

difference between theſe metals and thoſe, which are only corroded by the acid ſpirit. Theſe, which are only corroded, do not receive originally ſo much of the acid, as the other metals do. That theſe metallic cryſtals are rendered indiſſolvible in water by loſing part only of their acid ſpirit, is manifeſt, becauſe they remain of a greater weight than the original metal, whence they were made, and by a longer application of fire they will ſtill continue to part with more of their acid ſpirit, after they have been brought to the condition of being indiſſolvible in water. The greateſt part can ſcarce be brought to part with all their acid ſpirit by heat alone, however intenſe: but they require alſo the addition of ſome inflammable ſubſtance.

Thus the caſe, where metals are only corroded by the acid ſpirit, differs from the other ſolely by the quantity of acid, that unites to them. The third caſe, where water precipitates the metal, is a medium between the other two. Here the metal has aſſociated itſelf with only ſuch a portion of acid, as limits the quantity of water, with which it can unite itſelf.

Where the metal is only corroded, ſome portion of the watry part of the ſpirit ſeems to be united with it, though not enough to make the

mafs fluid; for by diftillation a portion of acid fpirit may be driven from it.

If filver diffolved in fpirit of nitre, after evaporation of the fpirit, be juft melted (which is done with a fmall heat) it makes the lunar cauftic. The acid particles of the fpirit, by being joined with thofe of the filver, give the mafs a very corrofive quality.

This mixt with falt, and rubbed upon brafs will cover it over with a cruft of filver. This is the means, by which the dial-plates of clocks are filvered.

In all the fore-mentioned proceffes of evaporating the menftruum from a metal, it has diffolved, the metal left behind retains ftill fo much of the acid fpirit, that it does not yet appear in its original form; but melted with any inflammable fubftance, or with an alkaline falt, not too highly calcined, it returns again perfectly to its metallic form.

Metals may be recovered from the menftruums, that have diffolved them, not only by evaporation of the menftruum; but by other means alfo, viz. by precipitation. This is done by putting to the fpirit fome fubftance, between which and the fpirit there is a ftronger action, than between the fpirit and the metal already diffolved in it.

In the first place some metals precipitate others. If a plate of copper be put into a solution of silver, the silver will fall to the bottom of the containing glass, and the spirit will act on and dissolve the copper. Iron will precipitate copper, and lixivial salts precipitate this metal, as it will any of the metals directly; and then the menstruum becomes no more than nitre dissolved in water, as we have before shewn.

In some of these precipitations the powder, which falls to the bottom, is pure metal; and by melting may be formed into a mass, in others the precipitating substance joins with the metal.

Silver is precipitated out of copper unmixt, especially if a little heat be applied, that the menstruum may act with full force on the copper. Copper will also precipitate gold pure out of aqua regia, and iron precipitates copper in the same manner from spirit of nitre.

On the other hand, tin put into aqua regia, that has dissolved gold, makes a precipitation of the gold, but united with some portion of the tin. The lixivial salts precipitate none of the metals pure. Gold thus precipitated falls in a powder called aurum fulminans, because, if gradually heated, it explodes like the pulvis fulminans, I have before shewn you.

Like-

Likewise as silver does not at all dissolve in aqua regia, so common salt, or its spirit put into a solution of that metal in aqua fortis precipitates the silver, but not in its metallic form; to restore that, the precipitation must be melted in a crucible, being first covered with some alkaline salt. By this method silver is obtained exceeding pure; for no gold will be retained by the aqua fortis, and when the salt is added, the aqua fortis is not disqualified from retaining all other metals except the silver.

As silver does not at all dissolve in aqua regia, nor mercury so freely, as in spirit of nitre; common salt put into a solution of these metals in spirit of nitre precipitates them; but not in their pure metallic form. The precipitation of quicksilver by common salt or spirit of salt makes mercurius precipitatus albus, and the precipitated powder by washing in much water is freed from the acid spirit loosely adhering.

There is another method in use for making white precipitate, from the composition, hereafter to be described, called corrosive sublimate. This is performed by dissolving equal quantities of pure sal ammoniac and this corrosive sublimate in water; and then making a precipitation with a solution of a fixt alkali salt.

But

But I have now described the most usual operations upon the metals by the acid spirits of nitre and of common salt, except only the use made of these spirits by the refiners of silver and gold. I have before shewn, how all other metals are separated from these two. They are best separated from one another by these spirits. When silver is dissolved in spirit of nitre; if any gold were in the silver, it will lie at the bottom in the form of a black or purple powder. In like manner, if gold containing silver be dissolved in aqua regia, the silver will be left in a white powder.

If these two metals are mixed in equal quantity neither of the spirits will act upon the mass: and if the predominant metal be not above three times the weight of the other, the acid spirit, by which that metal is dissolvible, will eat it out of the composition without destroying the form. This enables the essayers to perform an essay with great exactness in a very small quantity. They usually take about six grains only of the gold to be essayed, and refine it upon a test with about thrice its weight of silver; then beat the mass into a thin plate, and put it into aqua fortis, which eats out the silver, but leaves the plate intire, though brittle. By the plates keeping thus intire they are secure

cure against losing any minute portion of gold, which might falsify the essay. To be secure of extracting all the silver, a second quantity of aqua fortis is to be poured on the plate, when the first has done its office, and the plate at last washed with clean rain or river water. But as the plate will still look of a brown colour, before it is weighed, it is to be brought to its colour by igniting it with a degree of heat not sufficient to melt it.

Thus much concerning the acid spirits of salt and of nitre. The other two acid spirits deserve also to be considered.

By dissolving iron with oil of vitriol is made the medicine called sal martis; by its corroding quicksilver turbith mineral.

If filings of iron be put into oil of vitriol diluted with three or more times its quantity of water, a strong ebullition will arise, and the liquor become green.

If the flame of a candle be applied to the fume, which rises, while the metal is corroded, it takes fire. This is an instructive experiment; for it shews us, that in the vapour which rises from acid spirits, while they corrode metals, a part at least of the sulphur or inflammable substance lodged in the metal is carried off into the air.

If

If this ſal martis be kept in the fire in a crucible, till it becomes red, it makes a crocus martis. If this crocus be expoſed to a moiſt air, it will flow in it; and make what is called (though improperly) oleum martis per deliquium.

Oil of vitriol will alſo corrode lead in a ſmall quantity; copper it will diſſolve; upon the other metals, it will have no effect.

Copper, iron, and lead will diſſolve in vinegar, alſo tin, when calcined.

If tin calcined be diſſolved in diſtilled vinegar, and the diſſolution in part evaporated, and ſet to ſhoot, the ſalt reſulting is called ſalt of tin or ſal Jovis. In order that the vinegar may act on the tin, it ought to be very highly calcined, by being for a long time expoſed to the action of a ſtrong fire.

Lead, or any calcination of it, being boiled in vinegar, till the vinegar becomes ſweet; then the liquor evaporated in part, and ſet to ſhoot, affords a ſalt, which on account of its taſte, is called the ſugar of lead, or ſaccharum ſaturni.

Lead corroded by the fumes of vinegar becomes ceruſſe or white lead. The method of preparing ceruſſe is this. They fill pots in part with vinegar; then they roll up thin plates of lead and put them into the pots. By the ſhape of the pots the lead is kept up

from touching the vinegar, and the pots are alſo covered with a plate of lead. Theſe pots ranged in rows they bury in horſe-dung, by the heat whereof the ſteam of the vinegar riſes up and corrodes the lead; ſo that its ſurface becomes covered over with ceruſſe. After a time they beat off the flakes in a mill with ſtampers, then waſh the powder in water to ſeparate its groſs parts.

Filings of copper give vinegar a fine green tincture; which being evaporated in part will ſhoot into green cryſtals, which are verdigreeſe. In Provence verdigreeſe is made by ſtratifying plates of copper with the huſks of the grapes, after their juice is preſſed out for wine. Theſe, with the addition of ſome wine, corrode the copper, and turn it into verdigreeſe.

If the ſpirit of nitre, wherein quickſilver has been diſſolved, be evaporated, a white ſubſtance is left, which by a farther degree of fire turns red, uſually called mercurius precipitatus ruber, but in the preſent pharmacopœia mercurius corroſivus ruber, of excellent uſe in ſurgery. This freed, from what acid particles looſely adhere to it by often waſhing, is called arcanum corallinum. Some burn ſpirit of wine upon it. The reaſon of this operation will be readily underſtood from the proceſs we

formerly ſhewed of dulcifying ſpirit of nitre by mixing it with ſpirit of wine.

If filings of iron or ſteel be boiled with an equal weight of tartar, they will be corroded by the acid of the tartar, and make the chalybs tartariſatus of Bates.

If theſe filings mixt with twice their weight of tartar, be formed with a little ſpirit of wine into a paſte and laid by to ferment for three or four days; and this proceſs be repeated four times or oftener: two ounces of this ſteel tied up and ſuſpended in a pint of ſpirit of wine will impart to it a ſtyptic quality. This is the invention of Helvetius. But the proceſs being tedious, the college have ſubſtituted another in its ſtead.

The imperfect metals alſo are acted on by acid ſpirits.

The magiſtery of biſmuth is prepared by diſſolving biſmuth in ſpirit of nitre, and precipitating it by diluting the ſolution with a quantity of fair water.

LECTURE XVIII.

BESIDES the acid ſpirits, ſolid ſalts by virtue of the acid in them have very remarkable effects upon metals, and metallic bodies. Theſe we ſhall now proceed to conſider.

Corroſive ſublimate is made by mixing quickſilver with the groſs body of ſalt, and of nitre, with the addition of calcined vitriol and ſubliming the compoſition. What ſublimes is the corroſive ſublimate. Calcined vitriol alone with quickſilver will not make this ſublimate. Its uſe is the ſame as in making aqua fortis, only to diſengage more eaſily the acid ſpirits from the other ſalts.

This compoſition is made alſo uſe of in purifying gold, and in particular is uſeful to remove the laſt remains of any mixture, that may render the gold brittle. But gold may be refined by this ſublimate alone; if, while the gold is in fuſion, fragments of ſublimate are ſucceſſively thrown in upon it.

The reaſon for this effect of ſublimate may be learnt from experiments, Mr. Boyle made with it. He laid plates of copper upon ſublimate

mate in a retort and diſtilled it off from them. He made alſo the like experiment with ſilver and gold. By this proceſs the gold was not ſenſibly changed, but the copper and ſilver were ſo acted on, as to be reduced into a kind of roſin, which laid upon live coals would burn away with a flame.

If tin be mixt with an equal or double quantity of ſublimate, a liquor will diſtil from it, which Mr. Boyle makes particular mention of on account of its remarkable fuming.

In corroſive ſublimate ſo great a portion of acid is united with the quickſilver, as to render it diſſolvible in water. That the quantity of acid adhering is the cauſe of its being thus diſſolvible, is manifeſt, becauſe by only adding more quickſilver to the compoſition, as is done in making mercurius dulcis, the compound becomes indiſſolvible in water.

This corroſive ſublimate now deſcribed, by the violence of its acrimony is one of the moſt deſtructive of poiſons; but when mixt with a freſh quantity of quickſilver, after the rate of four parts of ſublimate to three of freſh quickſilver, and ſublimed again it becomes milder than before. By ſubſequent ſublimations without the addition of more quickſilver it grows ſtill leſs acrid. The third ſublimation makes

it a medicine very ſafely to be uſed internally, only ſtimulating very gently the bowels. If the ſublimation be repeated five or ſix times, it is ſtill ſofter.

This preparation, to diſtinguiſh it from the preceding corroſive ſublimate, is called mercurius ſublimatus dulcis, and more briefly mercurius dulcis.

At the firſt ſublimation a greater quantity of quickſilver being united with the acid of the ſublimate, that acid is in part buried in the quickſilver. And further, at each ſubſequent ſublimation a part of the acid is always expelled; for every time there riſes into the neck of the bolt-head an acrid part to be ſeparated from the reſt. Therefore after every ſublimation the preparation contains a greater portion of quickſilver in reſpect of the acid, than it had before. And thus, by being charged with an additional portion of quickſilver, it is rendered indiſſolvible in water, and ſo much leſs capable of acting on our bodies, as from a deadly poiſon to become a medicine only gently ſtimulating.

With corroſive ſublimate an eminent operation is performed upon antimony. If theſe two ſubſtances are mixt together, and diſtilled, there ariſes an unctuous congealed ſubſtance, called the butter of antimony. Many cautions are given

given by authors in regard to this diſtillation. That the retort be large enough to contain four or five times the quantity of the ingredients put into it; and that it be provided with a wide neck, leſt the butter ſhould riſe ſo faſt as to obſtruct it, and breaking the veſſel endanger the life of the operator from the fumes, which would be emitted. But the proceſs is daily performed with great ſafety in the retorts made at our glaſs-houſes, whoſe necks are always too large to be choaked up, though the retort be competently filled with the materials; provided only that the butter be melted down by approaching ſome hot body to the neck of the retort, where the butter lodges.

As ſoon as coloured fumes appear, the operation ſhould be ſtopped, that the butter, which is come over, may not be diſcoloured by them. From what remains in the retort may be ſublimed a ſubſtance of a red but ſomewhat dull colour, which is the true cinnabar of antimony. The quantity of this cinnabar is ſomewhat uncertain, depending upon the quality of the antimony. For in this proceſs the acid of the ſublimate quits the quickſilver, and unites with the regulus part of the antimony, by this means forming the butter; the ſulphur of the antimony unites with the quickſilver, and forms a

cinnabar. The quantity therefore of cinnabar depends upon the antimony's abounding in ſulphur. By this proceſs it appears, how near the ſulphureous part of antimony approaches to the nature of common brimſtone.

Authors differ greatly in regard to the proportion to be obſerved between the ſublimate and the antimony, ſome adviſe equal parts of each, others recommend three times as much of ſublimate as of antimony. If the ſublimate be uſed in too great a proportion, pure quickſilver will be found after the operation. If the antimony exceed, ſome antimony unaltered will be left. I have generally found, that with twice as much ſublimate as antimony the proceſs ſucceeds moſt completely. This proceſs ſo far as relates to the cinnabar being thus precarious, what has been uſually found in the ſhops under the name of cinnabar of antimony, is only a little antimony mixt with the ingredients for common cinnabar, before ſublimation.

The butter of antimony, by repeated rectifications, or being left open to the air, runs into a liquor, and is then called oil of antimony. This is uſed as a cauſtic, and is eſteemed for keeping itſelf confined to the place, on which

it

it is layed, without ſpreading, as other cauſtics do.

Butter of antimony being put into a large quantity of water, the antimonial regulus precipitates from it in the form of a white powder, called mercurius vitæ. This is a very ſtrong emetic; but has nothing of quickſilver in it, as its name would imply, but is the regulus of antimony waſhed from part of the adhering acid.

Antimony in powder well mixed with thrice its weight of nitre, and thrown by degrees into a crucible moderately heated, and then removed from the fire and waſhed in water, produces what is called diaphoretic antimony.

If upon butter of antimony be poured ſpirit of nitre, till all ebullition ceaſes, and then the fluid part of the mixture be drawn off, a powder will be left void of any emetic quality. This is called bezoar mineral, and has been held in high eſteem by many, and put in the firſt claſs of the medicines dignified by the name of alexipharmacs. But as it reſembles very much diaphoretic antimony, ſo it has no greater qualities. If it be melted with tartar, charcoal, or the like inflammable ſubſtance, it returns to regulus of antimony, as diaphoretic antimony does.

The

The liquor drawn off is called ſpiritus nitri bezoardicus, and will diſſolve gold, like aqua regia.

From all this we ſee beyond diſpute, that the ſpirit of ſea ſalt is an ingredient in butter of antimony; becauſe from the butter of antimony the ſpirit of nitre acquires a power of diſſolving gold; and of the ingredients uſed in that preparation, common ſalt is the only one, from whence the ſpirit of nitre can receive this power.

The acid ſpirit of ſea ſalt contained in ſal ammoniac will alſo act on the metals.

If this ſalt be mixed with an equal weight of filings of iron, and being well ground together they are put into a retort, with a fire raiſed by degrees to a due height, a ſublimation will fix itſelf in the neck of the retort tinctured by the iron. This mixt with the bottom and ſublimed again will be more deeply coloured than before. Alſo if to what then remains more ſal ammoniac be added, a like ſublimation may again be made. And by the repetition of the proceſs all the iron may be ſublimed.

In the ſame manner ſal ammoniac mixt with the colcothar of any of the vitriols, will carry up with itſelf their metallic part. Hence ſhoots martialis ammoniac.

If

If quickſilver, tin, ſal ammoniac, and flowers of ſulphur are mixt together in juſt quantities, and put into a bolt-head, heat being gradually applied at length a ſeparation will be made, and a light brittle ſubſtance of a golden colour found in the middle which is called aurum muſivum. The form of the proceſs is this, firſt, to melt the tin, and then add the quickſilver to it, which readily mixes with the tin, and, when cold, compoſes with it a brittle body; and this, when powdered, is to be well rubbed with the other ingredients: when the ſublimation is completed, there comes out of the bolt-head a fetid ſmell reſembling that of rotten eggs.

Though the acid ſpirit extracted from vitriol will not operate on all the metals: yet the ſame acid in ſulphur will act upon every one, upon all but gold and tin alone, and upon them, if it be firſt melted with a lixivial ſalt.

In order to calcine the metals with ſulphur it is uſual to reduce them to ſmall parts, that they may the ſooner be penetrated by the ſulphur. This may be done either by granulating the metal, or by ſtratifying thin plates of it with the brimſtone. This method of ſtratification, as the chemiſts call it, is uſually deſcribed thus; that the bottom of a crucible be firſt covered

with

with sulphur; then a plate of metal laid upon it; and this being also covered with sulphur, another plate of metal laid on, thus proceeding till all the plates are put into the crucible, the uppermost plate being also covered with sulphur. But the same intention may be more compendiously answered by thrusting bits of the metalline plates perpendicularly into the sulphur, after that has been put into the crucible.

An expeditious method of granulating the metals is by pouring them, when melted, into water from some height. If the metal is not a valuable one, it is usual to pour it through a birch broom.

Tin is often reduced to powder by pouring it melted into a box, and at the instant it begins to set shaking it about. The like may be done, though not quite so easily with other metals: for the metals in the point of their change from a fluid state to their solid and malleable consistence are brittle.

If quicksilver be stirred into melted brimstone, it will incorporate with it, and upon their union the mixture usually takes fire. It is immediately extinguished by putting a close cover upon the vessel, in which the matter is contained. This mixture sublimed is called factitious cinnabar from its near resemblance to the native,

tive, which is a natural union of sulphur and quicksilver. The painters use this preparation under the name of vermillion.

If a bar of iron be heated glowing hot, it melts down at once into a brittle calx upon the contact only of a roll of brimstone.

This calx dropping into water, freed from the brimstone and reduced into a very fine powder is called chalybs cum sulphure preparatus.

LEC-

LECTURE XIX.

HAVING inquired into the principles of which metals consist, we shall now consider, in what form they are found in the earth, and by what arts they are extracted from their respective ores.

Metals are sometimes found pure, sometimes mixt with and concealed in other substances.

All the gold, we have, is found in the visible form of gold. Some is found in small grains, and dust among the sands of certain rivers, from whence it is separated only by agitating the sand in water, whereby the gold, having a much greater specific gravity than the sand, subsides, and collects together at the bottom of the vessel, in which the operation is performed. Thus is collected all the gold we have from Africa: and here it is separated from the small remains of sand still concealed in it by melting it with nitre. The nitre converts the sand into a glass, which rises out of the metal upon its melting, and swims upon it in a separate body.

In America the gold is found in veins within a white rocky spar: from whence it is extracted only

only by grinding with quickſilver. Quickſilver, as I ſhall ſhew hereafter, will unite with, and, as it were, diſſolve gold: and therefore in grinding the golden ſpar with it, the gold is imbibed and ſeparated clean from the ſpar.

In the ores, where ſilver is the predominant metal, it alſo is uſually ſeen in them in its metallic form. And in America is ſeparated by quickſilver, as gold is, only with ſome larger apparatus, and ſome additional operations to prevent other ſubſtances, often found in the ore, from obſtructing the quickſilver in its imbibing the metal.

Gold is ſaid to be contained in ſome ſubſtances, where it is not ſeen, in its metallic form; as in particular in ſea-ſand, and in ſome flints; but not in quantity ſufficient to make the extraction of it profitable, except where it is found in ores of other metals.

A great deal of ſilver is extracted from ores, where it does not appear viſibly. A great many lead ores contain a portion of ſilver. Moſt of thoſe called ſilver mines in Europe are mines of lead enriched with ſilver.

The other four metals, copper, lead, tin, and iron are ſeldom met with in their metallic form. Copper is, I think, the only one ever ſo found.

These

These metals are generally in their ores corroded by an acid ſpirit, which muſt be ſeparated from them in order to obtain the metal pure.

This acid ſpirit is of the vitriolic kind, as that is the acid, which is found in brimſtone, wherewith we have already obſerved, that marcaſites abound. And marcaſites generally accompany metallic ores; and are themſelves ſcarce ever free from ſome metal.

Beſides this acid ſpirit there is alſo found in many of the ores themſelves the uſual contents of the pyrites, ſulphur, and, not unfrequently, arſenic; inſomuch, that in calcining ores theſe ſubſtances viſibly exhale from them.

Thus ores are compounded of theſe ſeveral parts. The metal either in its complete form, or eroded by an acid; ſtony and earthy parts; beſides the contents of the pyrites ſulphur and arſenic. Theſe laſt, if left in the ore, when it is melted, will corrode the metal, and prevent its receiving the due metallic form. But as theſe ſubſtances are both volatile, they may be exhaled from the ore by a proper degree of heat, before it is melted.

Now as metals are compounded of two ſubſtances, one, which conſtitutes the bulk of the metal, and another, whence it receives its me-

tallic form, the art of ſmelting conſiſts of theſe two particulars; in the firſt place to free the ore from the acid, which has corroded the metal, and from all other ſubſtances that may do ſo in the melting; in the ſecond place to provide, that the metal be furniſhed with a due portion of the ſubſtance neceſſary to maintain its metallic form. This we have ſhewn to be a ſubſtance common to metals with other bodies, being that, to which inflammable bodies owe their power of burning.

The greateſt part of copper ores contain ſo much of this inflammable ſubſtance; that the the art of extracting copper from its ore, called by the workmen ſmelting, conſiſts in freeing the ore from its acid ſpirit.

They commonly firſt burn away the groſſeſt part of the ſulphur, which lyes mixt in the ore, in a furnace not capable of giving a degree of heat ſufficient to melt the ore; and after this light roaſting is performed, they remove the ore into another furnace of the ſame kind; but ſo built as to give a greater heat; and in this furnace the ore is melted. Theſe furnaces are one of the two kinds of reverberatory furnaces, I deſcribed at the beginning of theſe lectures. One is that wherein we lately diſtilled ſome of the acid ſpirits, where the veſſel containing the

ſubject to be diſtilled was ſo ſuſpended within the furnace over the fire, that it hung in the middle of the flame. But to theſe now mentioned the name of reverberatory ſtill more properly belongs; for in theſe furnaces the fire being made on one ſide the bed, which holds the ore, and the exit for the flame and ſmoke on the oppoſite ſide, the flame is brought over and beat down upon the ore. The roof of the furnace deſcends in paſſing from the fire-place to the exit for the ſmoke; for the flame of the fire diminiſhes, as its diſtance from the fire increaſes; and by this ſtructure of the furnace the ſpace between the ſurface of the ore, and the roof of the furnace being alſo diminiſhed, the flame, when leſs in quantity, is condenſed, ſo as to give the ſame degree of heat. By this means the whole ore is equally heated.

(Here the model of the copper furnace.)

It is ſo difficult to diſengage copper from its ore, that in moſt ores there ſeparates from the ſlag upon the melting only a blackiſh brittle ſubſtance impregnated with copper. This the workmen call a regulus of copper. From this by a ſecond roaſting long continued and ſubſequent melting, both performed in the latter furnace, copper will ſeparate.

Some

Some rich ores yield copper upon the firſt melting. It is found advantageous to work richer and poorer ones mixt together: for the rich ores are ſometimes defective in the inflammable part, and the poor ores abound with it.

When real copper is thus ſeparated from the ore; there yet requires farther roaſting and other management to render it pure: many ores abound with iron; in theſe the copper is rendered coarſe and brittle by a mixture of this metal with it; which muſt by ſubſequent calcinations and meltings be roaſted out. If in theſe operations the copper is deprived of its proper portion of the inflammable ſubſtance I obſerved to be neceſſary to metals for the ſupport of their metallic form, this is to be reſtored by adding ſome inflammable ſubſtance, that will not too ſoon be diſſipated, ſuch as tartar, charcoal, and the like. But while the copper is thus reſtored, the iron will remain burnt, and thereby be ſeparated from the copper.

This method of ſmelting in the reverberatory furnace is practiſed only in our iſland, nor here above three or four ſcore years.

It was firſt begun upon copper; but ſoon after the like method was put in practice upon lead ore.

Lead ore contains ſo much of a ſulphureous or inflammable part, that by roaſting only a large portion of metal will ſeparate from it.

Lead ore is roaſted in the ſame kind of furnace as copper ore, but, while it is roaſting, it becomes ſoft, and, as it were, half melted. To prevent its ſoftening too faſt, they throw lime in upon it, which keeps the ore dry. They ſtir the ore and lime together with long irons through holes made in the ſides of the furnace for that purpoſe. The metal here melts from the ore during the roaſting, and is let out, at certain periods, by a hole made for it in the ſide of the furnace.

(Here the model of the lead furnace.)

Lead ore does not abound ſo much with the inflammable ſubſtance ſo often mentioned, as copper ore does: inſomuch that a part of the metal is ſtill left in the ore, and wants the addition of ſuch a ſubſtance to produce it.

To this end they melt their ſlags by the blaſt of bellows upon a hearth mixt with foſſil coals already ſo far burnt, as to have their humid part evaporated, and paſt ſending out a groſs ſmoke. Such coals are called coakt coals. Coals thus treated are in reſpect to crude coals, what charcoal is to unburnt wood.

These

These ſlags would melt as thin in the furnace as here. But here they receive from the coals, while they melt, an inflammable part neceſſary to their ſupplying more metal. After all, when the ſlag has laid a time expoſed to the air, it will yield more lead by being melted upon this hearth.

(Here the model of the ſlag-hearth.)

In ſome countries of England the firſt part of the lead is ſtill melted from its ore with billets of wood. This is done in a ſquare furnace, into which the wood is firſt thrown in ſufficient quantity to make the proper fire, which is blown up with bellows moved by a water-wheel; and upon this is thrown the ore, from which in melting the lead runs out: when that ceaſes, the ſlag is raked out, and another fire made up with freſh ore. From theſe ſlags is extracted the remaining lead in a ſlag-hearth with the pit-coal of the country. On Mendip hills, they uſe no pit-coal, but wood, and charcoal.

(Here the Derbyſhire and Mendip-hills furnaces.)

The ores of tin and iron are defective in the inflammable part. The metals therefore are not to be ſeparated from theſe, without adding ſome material from whence this inflammable part may be communicated. Tin ores are now melted in Cornwall in reverbera-

tory furnaces, as copper and lead ores; but not roasted in them. They are spread over with small coals, and melted directly.

Thus we now smelt in England copper, lead, and tin, by the help of fossil coals. In all other countries metals are smelted with charcoal. The scarcity of charcoal, and great plenty of fossil coals with us, gave occasion to our proceeding in a different method. We made no copper in England, till the present way of working was invented. Lead and tin we have wrought upon time out of mind. Our island has been the principal source of tin from the earliest accounts of time, and continues still to be so for both metals.

Scarce any successful method has yet been found of communicating to iron ore the inflammable part from fossil coals.

With charcoal the method of smelting metals is this. They first lightly roast the ore to expel the loose sulphur, laying the ore upon wood or small charcoal set on fire. Then they pound the ore, and put it into the smelting-furnace mixt with charcoal. This furnace is only a building of brick, open at top, where the ore and charcoal is thrown in with baskets alternately, and having a small hole on one side at the bottom, before which a bason is made to receive the metal,

tal, as in melting it flows out from this hole. This furnace Agricola deſcribes with a cavity equally wide from the bottom to the top. But at preſent in our iron furnaces, and in the other furnaces abroad alſo, its cavity is made wideſt in the middle, narrowing both upwards and downwards. Toward the bottom of the furnace the noſes of two pair of bellows enter, which blow alternately and are moved by a water-wheel. By this vehement blaſt, and the great ſtrength of the charcoal fire, the acid ſpirit is expelled from the ore, and the fuel at the ſame time ſupplies the metal with a due quantity of the inflammable ſubſtance neceſſary to it. In iron lime is always added to imbibe the acid ſpirit of the ore, and thereby aſſiſt the fire in ſeparating it from the metal.

Iron ore before it is thrown into the furnace undergoes a ſlight degree of roaſting by being piled up with ſmall charcoal, which being ſet on fire by its heating the ore renders it brittle, whereby it is more eaſily broken into ſmall fragments.

(Here the model of the iron furnace.)

Iron thus melted from the ore is not malleable, but requires farther management to give it that property. This is effected in the following manner. They heat it with charcoal in a

forge, where at firſt it melts, but at length by imbibing from the coals a larger portion of their inflammable part, and the ſeparation of a quantity of a glaſſy droſs (called by the workmen cinder) it grows gradually tougher, and acquires the ſoft, but tenacious conſiſtence, which malleable iron has, when ſtrongly heated. If it be not brought to a malleable condition by one melting, it is heated over again in like manner; but the firſt heating is ſufficient for the greateſt part of the iron, which is wrought upon to be rendered malleable.

As the iron comes thus hot out of the fire; after having firſt received a few blows with wooden mauls or hand-ſledges, it is carried, and held under the blows of a large hammer, that is raiſed up by a water-wheel. This hammer beats the ſmall remains of ſlag or cinder out of the metal, and unites it into a cloſe body of malleable iron. Afterwards this iron by repeated heatings and hammerings is beat out into bars of different ſizes, and fitted for the market. But none of the ſubſequent heatings are ſo great as the firſt. In forming the bars they beat out the middle part firſt; then heat it at a leſſer forge, and beat out the ends.

(Here the forge-hammer.)

Iron is leſs fuſible than its cinder or ſlag; which is the reaſon of uſing the hammer to beat the laſt remains of the ſlag out of it. This is an operation peculiar to iron; for all other metals, by their fuſibility, run liquid from their ſlag. But as iron is leſs fuſible than its ſlag; ſo the ſlag of iron is not ſo fuſible as to flow perfectly from the iron without the aſſiſtance of the hammer to force it out. All ſlag flows more or leſs tenacious after the manner of glaſs.

In iron ores, that are very rich in metal, good part of the iron may be obtained from them, with a much leſs fire than what is required to melt the other ores.

Theſe ores may be originally wrought at a forge, and the iron rendered malleable at one operation. Theſe forges have a pit, which being filled with coals, and ore laid upon them; as the ore ſoftens it ſinks down into the pit, and the ſlag runs from it, as in the other caſe of fuſible iron. The iron thus purged is taken from the pit, and hammered clean from the remaining ſlag, as in the other caſe.

But here alſo muſt be put into the fire along with the ore a quantity of lime; that the lime, by diſſolving the ſulphureous part of the ore, may facilitate the ſeparation of the ſlag. How-

ever

ever these forges seldom or never extract the whole quantity of the iron from the ore.

In smelting silver or gold ores, where these metals are got by melting the ore, they put a quantity of lead in the bason, which receives the metal. This lead keeps melted by the heat of the furnace, and imbibes the silver and gold from the slag. The metal is afterwards separated from the lead in the manner described, when I shewed the method of refining these metals by the help of lead.

Our refiners have an operation something similar to this, which they call melting their sweep. In parting silver from gold by aqua fortis, it is no uncommon accident, by the breaking of their glasses, to have their metal mixt with sand. Such sand, together with any dirt, wherewith they suspect metal may be mixt, they at certain times operate upon to recover the metal. It is performed in a furnace, like that, wherein silver is smelted from its ore by charcoal. Into this furnace is thrown the sweep, and litharge mixt together. In the charcoal fire the litharge is reduced, and runs out in the form of lead, having imbibed, and bringing with it what silver or gold was mixt in the sweep. To effect more perfectly the separation of their metal from

the ſand and dirt of the ſweep, they likewiſe from time to time throw in the ſlag or cinder of iron. This melts the ſand, and ſeparates it more effectually from the metal. And congealing as ſoon as ſoon as it comes out into the air; by a large poker they keep this glaſſy and tough ſlag up in the mouth of the furnace, and thereby regulate the running of the metal at pleaſure. The cinder of iron is better for this uſe than the ſlag of any other metal; becauſe it is of a more pure glaſſy ſubſtance than the reſt.

There is alſo another method, which was mentioned above, of ſeparating theſe metals from their ore, which in ores, where the metal exiſts in its metallic form, makes the moſt perfect ſeparation. After the ore has been freed by calcining from its looſe ſulphur, when that is neceſſary, it is well mixt with quickſilver by grinding them together. The quickſilver unites itſelf with the ſilver and gold, and by that means ſeparates them from the ore. The quickſilver is ſeparated again from the ore, partly by ſtraining through leather, and partly by diſtillation. Before quickſilver is mixt with the ore, it is neceſſary to free the ore from its looſe ſulphur, if the ore abound therewith: otherwiſe the

the quickſilver will lay hold upon this ſulphur, and not act upon the metal.

Copper is ſo ſtubborn a metal to free from its ore, that once ſmelting even with charcoal will not often do it; but only produce a brittle regulus, which muſt undergo ſubſequent roaſtings, and then be melted down again before pure copper can be obtained from it.

What has been ſaid may ſuffice to give a general idea, how metals are extracted from their ores. But I intend to explain more particularly the method of examining ores in ſmall quantities, whereby the goodneſs of any parcel may be judged of. This art of eſſaying admits of ſeveral compendiums not to be put in practice with profit in the great works; the account of which, and illuſtration by experiment, I deſign for our next meeting. I ſhall here only in general obſerve, that as ores come out of the mines mixt with earthy and ſtony ſubſtances; all ſuch heterogeneous mixtures, which are light enough to be waſhed off are ſeparated from the ores by that means, before they are carried to the ſmelting-houſes: and therefore it is after this waſhing, that they are uſually eſſayed. But iron ores are in this to be excepted: they do not

in general require washing; for they lie in the earth in a different manner from all others. The rest of every kind run in veins through the rock, which contains them; but iron ores compose the intire body of the rock or hill.

LEC-

LECTURE XX.

WHEN the ſmelter purchaſes ores from the mines, it is neceſſary for aſcertaining their value to examine by eſſaying a ſmall quantity what portion of metal the ores contain.

Though this eſſay may be made by the ſame means, as the ſeparation is performed in the great works, yet certain compendiums and aſſiſtances are here uſually made uſe of by additional materials, which cannot in the larger operations be admitted with profit. Theſe additions are uſually called fluxes: and are of different kinds.

As ores in eſſays, as well as in the great works, are divided by ſmelting into two parts, the metal itſelf, and a droſs or ſlag of a glaſſy conſiſtence ſwimming upon it, while they are both fluid; ſome fluxes have no other uſe than to aſſiſt in rendering this melted ſlag more liquid, that a leſs degree, or ſhorter continuance of the fire may melt it thin enough for the metal to fall freely through it. Theſe fluxes are the three ſalts, borax, nitre, and the alkaline ſalt of vegetables;

vegetables; for any of these will melt with stony substances into glass. Glass is also an expedient sometimes made use of in very stubborn slags; but it ought to be of the most fluxile kind, except flint-glass. That must not be used, lest the lead in its composition should be reduced in the operation, and by joining with the metal of the ore falsify the essay.

These fluxes are always useful, whenever there is danger, that the metal, after it is separated, may be burnt, and thereby diminished, by the strength or continuance of the fire required to liquify the slag; but they are most necessary, when the fire is weak.

Another sort of fluxes regard the metal itself, which are either such as will furnish a due portion of the requisite sulphur, when that is wanting; or such, as may absorb whatever substances in the ore might corrode and destroy the metal.

The fluxes in common use are often compound in their effects, partly supplying one office, and partly another. Of this kind is that called the black flux. We have seen tartar and nitre mixt in equal quantities burn together into a simple alkaline salt. But if the tartar be taken double to the nitre, and the mixture be set on fire, while one half of the tartar is reduced with

the

the nitre into an alkaline ſalt, the reſt is only burnt to a black coal. This compoſes the black flux; and when mixt with any ore in melting, the coal is fitted to ſupply the requiſite inflammable part to the metal, while the ſalt attenuates the ſlag. This flux is apt to cauſe a great intumeſcence, and endanger the carrying over ſome part of the ore out of the melting pot. But this inconvenience is remedied by covering the whole mixture with common ſalt, which diſſolves the tenacity of the ſurface, and prevents the intumeſcence.

In lead ores iron is the moſt commodious flux; for this metal will ſtrongly unite with ſulphur and even arſenic, thereby imbibing all ſuch ſubſtances in the ore, as might deſtroy the lead; and at the ſame time will ſupply the lead with what inflammable part it may want, itſelf abounding therewith, as we have ſeen by its burning and flaming with nitre.

But this flux cannot be uſed in any other ore, becauſe it will join itſelf with the metal of the ore; but with lead it will not join.

Tin ore may be melted with a ſimple flux, this ore requiring no abſorbent; but only a little charcoal, or ſome ſuch inflammable ſubſtance to give the metal its form; though as it is a metal the ſooneſt burnt of any, and its ore has

has a ſlag not very eaſy to melt, ſome ſalt to facilitate the flowing of the ſlag will be a very uſeful addition. This may be borax. But before melting it is uſual to waſh away as much as poſſible of the ſtony and other terreſtrious ſubſtances, with which the ore is mixt, all ſuch ſubſtances being lighter than the grains of ore, wherein the metal is contained; and if the ore is mixt with mundics, it is expedient before waſhing to roaſt out the volatile part of thoſe ſubſtances.

Iron ore requires charcoal to give the metal its form, and ſome alkaline material to abſorb the acid ſpirit; for which purpoſe lime is the moſt effectual; ſo that lime with a third or fourth part of charcoal makes the beſt flux for this ore, with which it may be melted, after it has firſt been made red hot by itſelf, that in ſmelting it may not upon the firſt heat fly out of the melting pot. Here the chief difficulty is to make the fire ſtrong enough. The cinders of coals, if not too much burnt, perform this eſſay beſt.

Copper ore is the moſt difficult to ſmelt of any. It joins ſo freely with all other metals, and is ſo readily corroded both by acids and alkalis, that there is no commodious material known for imbibing either the ſulphur contain-

ed in the ore or the acid ſpirit, with which the metal is joined. They are both to be expelled by roaſting. For this reaſon copper ore is ſometimes eſſayed without any addition, except perhaps ſome ſalt in the melting to promote the fluxility of the ſlag; but is roaſted or calcined, and then melted down, as in the larger work. Here one roaſting and melting will not bring copper out of moſt ores. But if the work has been carried on well, the copper will appear at the ſecond melting. To facilitate the roaſting, the ore is to be beaten to a groſs powder, and be kept ſtirring all the time it is in the fire, that it may not clod together, as it will do, were it left to itſelf. If it happen to clod much, it ſhould be removed from the fire, and powdered again; for it roaſts, while in lumps, but very ſlowly. The chief art in this operation is to judge, when the ore is ſo far prepared, that metal may be expected from it: for the roaſting may be continued, till the metal ſhall be calcined, and burnt up to droſs. When this has happened, it may be known by the colour of the ſlag, which then appears tinged with the metal. The remedy in this caſe is to melt the ſlag down again with ſome material proper for reſtoring the inflammable part, which has been burnt out. For this purpoſe either

charcoal

charcoal or tartar may be uſed: tartar will the leaſt thicken the ſlag.

When the ore firſt grows hot, it feels ſluggiſh and heavy, like flower, under the rod, wherewith it is ſtirred. By degrees it grows lighter and feels dry like ſand. By this change the roaſting is to be judged of. It is complete, when all the ſluggiſhneſs upon ſtirring is gone. At this time alſo it loſes its red colour upon the ſurface, as ſoon as the ſtirring is intermitted, whereas before the redneſs continues ſome time upon it.

But copper ore may be more expeditiouſly eſſayed by roaſting, till it has loſt all ſmell, and then melted with borax or ſome ſuch ſalt to promote the fluidity of the ſlag, and alſo a little charcoal or tartar burnt black, leſt the metal ſhould have been in any meaſure calcined. Though care ſhould always be taken not to roaſt the ore more than neceſſary; for metals calcined never are reſtored again in full quantity.

In authors is found a much greater compoſition of fluxes, than I have recommended. But I apprehend the weakneſs of their fires rendered ſuch great apparatus neceſſary, and theſe copious fluxes are attended with an inconvenience: by their bulk they ſo fill the melting pot, that

but a very ſmall portion of the ore can be taken for the eſſay.

In relation to ſilver and gold ores, they are uſually eſſayed by putting them to lead in fuſion; whereby, while one part of the lead calcines and unites with the ſtony part of the ore, the reſt imbibes the metal, from whence it is afterwards to be ſeparated. If the ores are ſtubborn in melting, litharge ſhould be added to them, or even the glaſs of lead before mentioned. If the ores contain ſulphureous or arſenical ingredients, thoſe are previouſly to be roaſted out.

In eſſaying theſe ores the lead, into which the ore is put, (either alone, or with litharge or the glaſs of lead, if the ore be of difficult fuſion) is uſually contained in a veſſel made in the manner of a teſt; but, inſtead of bone aſhes, of ſome earth. The reaſon of which is, that the lead may not be imbibed, before it has fully liquified the ore. The earth of theſe veſſels ought to be of a kind as little liable to vitrify and be eroded by the lead, as may be; and when the lead is covered over with ſlag, and that melted ſo thin, that the metal in the ore may eaſily fall through it, the veſſel is to be removed from the fire, and when cold the ſlag ſeparated from the lead, which is to be afterwards

wards roasted upon a test of ashes, that the metal of the ore may be received pure. The whole process may be performed upon a test of bone ashes, if the quantity of ore essayed is so small, that as much lead may be used without rendering the operation tedious, as will suffice, before it shall be imbibed by the test, for liquifying duly the ore.

But a more concise method is to melt the ore in a crucible with litharge, or, if it be a stubborn ore and require a long and violent fire to be brought to fusion, with glass of lead; and then by the addition of charcoal to restore the lead, which will carry down with it the metal of the ore. If the ore require a long or violent fire, the glass of lead is to be used, lest litharge should corrode the melting pot.

LECTURE XXI.

HAVING ſhewn how the true metals are ſeparated from their ores, we ſhall next conſider the imperfect metals, and their ores.

Of the imperfect metals quickſilver differs from thoſe properly called metals by its perpetual fluidity; the reſt, which are ſolid, by the want of malleability, though they have an external appearance and weight reſembling that of a true metal, and are fuſible in the fire. They differ from glaſs in not being tranſparent, and from ſalts by not diſſolving in water. The chief of theſe, as has already been mentioned, are biſmuth, ſpelter, and the metallic part of antimony.

Quickſilver is frequently found in its metallic form; ſo that it is ſeparated from the earth containing it, partly by waſhing it in water only, or at moſt by heating it. For quickſilver with a degree of heat ſcarce exceeding that which will melt tin, is rendered volatile; and therefore ſo much of the quickſilver as does not waſh out of the ore, is ſeparated from it by a ſimple diſtillation.

Native

Native cinnabar is an ore of quickſilver, from which the metal cannot be obtained without more art. It is a union of quickſilver, and ſulphur. And, as we have ſeen, both lixivial ſalts and lime act upon and diſſolve the ſulphur, ſo either of them mixt with this ore cauſe the quickſilver to ſeparate from it upon diſtillation. The filings of iron will produce the ſame effect.

A moderate degree of heat without any additional art ſeparates biſmuth from its ore, which is little elſe than biſmuth already formed, intermixt with earthy parts.

Agricola, who is an author, that always ought to be conſulted upon the ſubject of metals, deſcribes the manner of doing it thus. The ore is laid in a cavity, for the moſt part made in the earth, ſometimes round, ſometimes a long trench; and billets of wood being laid over upon the ore, and ſet on fire. The biſmuth ſoon runs from the ore, and flows out into a receptable from the cavity, where the ore is contained, through a paſſage left open for it.

Spelter bears ſome analogy in its properties to biſmuth. It is produced near Goſlar in Germany, after this manner. There are lead mines near Goſlar, which contain a particular kind of ore. It is a ſtubborn one, very difficult to melt. From this ore ſublimes in the melting a ſub-

ſtance, which is found, after the melting is over, ſticking to the inſide of the furnace. This ſubſtance they ſhake down into a ſmall fire made at the bottom of the furnace; where it melts. This is ſpelter. The principal conſumption of biſmuth is by the pewterers, who make with it a kind of ſolder.

Spelter is chiefly uſed for ſoldering by the copper-ſmiths, and braziers; and for making a mixt metal much in uſe; now uſually called Bath metal; but formerly prince's metal, the invention of it being aſcribed to our prince Rupert.

Spelter is remarkable for waſting in flame, when melted.

Antimony, the third mineral now under conſideration, comes to us prepared only by melting down the ore, and caſting it into molds; whereby the antimony is ſeparated from the looſe earth, wherewith it may be mixt.

But this antimony ſtill reſembles more a metalline ore than a metal; by other methods a metallic part is ſeparable from it, as much reſembling a metal as biſmuth and ſpelter; but brittle and even leſs capable of bearing the hammer than ſpelter.

Antimony conſiſts of two parts. A ſulphur not very different from common brimſtone, and another part, as has been now ſaid, which may

be made to appear under a metallic form, except that it is not malleable.

We have ſeen nitre inflame with ſulphur. In the ſame manner nitre will burn out the ſulphur from antimony, and leave the reſidue a calx, (called diaphoretic antimony deſcribed already) which may be brought to a metallic form. For this purpoſe it is only neceſſary to melt it with ſome inflammable ſubſtance. The metallic body thus produced is called the regulus of antimony; and being taken into the ſtomach vomits very ſtrongly.

If only equal quantities of nitre and antimony were mixt, and thrown together into a hot crucible, the reſult will exhibit a ſubſtance ſtrongly emetic, though it will be a little leſs violent than the forementioned regulus of antimony. This preparation, uſually called hepar antimonii and crocus metallorum, is named in our preſent pharmacopœia crocus antimonii. The practical chemiſts have gradually reduced the quantity of nitre to half the weight of the antimony, and only ſet the mixture on fire.

The emetic quality of this medicine will be rendered yet ſomewhat more moderate by boiling it with an equal weight of the cream of tartar, till they are united. This medicine is called tartarum emeticum.

The

The regulus of antimony is not uſually prepared in the manner propoſed above. The proceſs is ſhortened thus.

Antimony and tartar and nitre being mixt in due proportion; this mixture by little and little is to be thrown into a hot crucible; and when the whole is put in; it muſt remain in the fire, till all ſparkling ceaſes, and the matter is well melted; then being poured out into a warm iron mould a little greaſed, as ſoon as cold a compact metalline ſubſtance will be found at the bottom, which eaſily ſeparates from what is over it. This is called the regulus of antimony.

The quantity of tartar ought to be equal to twice that of the nitre, and the antimony may be from an equal weight with the tartar to a third part more.

Iron alſo acts very ſtrongly on ſulphur, and there is another method of ſeparating this regulus, by the uſe of that metal.

Take any quantity of antimony and about half as much iron. Let the iron be heated in a crucible till it becomes red hot; then let the antimony be thrown in upon it. When the antimony begins to flow, let nitre be thrown upon it by degrees, till the quantity thrown in equals near a quarter part of the antimony. After this let

let the matter flow with a ſtrong heat: then the iron, being corroded by the ſulphur of the antimony, flows along with the reſt of the materials into one uniform fluid maſs. When the matter flows like water, let it be poured out as before; and a large quantity of regulus will be found at the bottom. Melt this regulus again and throw in upon it a fourth part as much freſh antimony, as was firſt uſed; and, when this alſo melts, add as much nitre as before; and, when the matter flows with a ſtrong heat, let it again be poured out, and a regulus will be found at the bottom with freſh droſs or ſcoriæ at top.

Let this regulus be melted again with the ſame quantity of nitre alone, and freſh ſcoriæ will ſeparate from it.

Let the regulus now produced be melted again with the ſame quantity of nitre, and more ſcoriæ will ſeparate. In theſe two operations, eſpecially in this laſt, the matter muſt flow with a very ſtrong heat. But, if the heat be very intenſe, it muſt not be too long continued, leſt the antimony corrode the crucible, and be loſt. If the heat is more moderate, a longer continuance of it will be neceſſary. If the proceſſes have been well performed, there appears now upon the regulus a kind of ſtar.

The

The regulus of antimony, as I obſerved above, is an exceeding ſtrong vomit; and has this remarkable property, that infuſed in a liquor it communicates its emetic quality in proportion to the quantity of the liquor, and not in proportion to the quantity of the regulus infuſed. This however is no more than, that the liquor will imbibe only a certain quantity from the regulus; and when ſaturated will receive no more. What the regulus parts with is very minute in quantity, and not to be diſcerned under a long time.

Of this regulus cups have been made, in which liquor being poured would in a night's time acquire an emetic quality. The regulus, that has impregnated wine with an emetic quality, will ſtill impregnate more wine with the ſame quality.

If we conſider, how vaſt a quantity of liquor will receive the emetic quality from a ſmall portion of the regulus, it will appear to be a dangerous medicine to be given in ſubſtance, for the vomiting will ceaſe only by the medicine's being totally returned out of the body.

The ſcoriæ ſeparated from the antimony in preparing the regulus have alſo an emetic quality, and will run, being expoſed to a moiſt air, into an emetic liquor; eſpecially the ſcoriæ in

the

the latter way of making the regulus. This liquor is called the golden oil of antimony from its colour. These scoriæ receive their emetic quality from some portion of regulus contained in them; for, if they are melted again with a little tartar or charcoal dust, more regulus will subside from them.

Antimony is one of the best materials for the perfect purification of gold; for if this mineral and impure gold be melted together, the sulphur of the antimony will unite with and retain every other metal, with which the gold may be mixt, while the gold subsides, accompanied with so much of the reguline part of the antimony, as its sulphur has quitted; and this regulus in a strong fire will fume away, leaving the gold pure.

To the present class of substances arsenic is most properly to be referred. It resembles antimony in an emetic quality, but is so violent as to be an almost inevitable poison to every creature, that shall have taken it into the stomach. Calcined with nitre it loses its activity altogether, and becomes a harmless calx; melted with iron it yields a metallic part, from its resemblance to that part of antimony, usually called the regulus of arsenic.

Arſenic is contained more or leſs in moſt mundics; but is uſually extracted from a particular kind called cobalt. Cobalt calcined and mixed with ſand is uſed by the potters under the name of zaphor, being their blue. Zaphor melted with an alkaline ſalt is ſmalt. In the calcination arſenic riſes in ſmoke, and is collected in a long and winding chimney, where it ſettles in the form of a white flower.

Some cobalts are unfit for making ſmalt or zaphor. But from theſe alſo arſenic is ſublimed. As arſenic in its firſt ſublimation riſes in form of flowers, it is ſublimed over again from iron pots into an earthen cover of a cylindrical ſhape, where it unites into a cake in the form in which it is imported hither.

This arſenic is white. There are two compoſitions made from this; one called yellow the other red arſenic. The yellow is produced by ſubliming white arſenic with a twentieth part of brimſtone, red arſenic is the reſult of the like proceſs with twice the quantity of brimſtone, and a farther addition of a particular kind of cobalt, called in the German language kupfer nikel.

Black

Black lead, wherewith pencils are made, a mineral, almoſt peculiar to our country, bears alſo ſome reſemblance to antimony. The people of the country, where it is dug up, infuſe it in beer or wine for an emetic. But this ſubſtance is neither volatile, nor will melt with any degree of heat.

LECTURE XXII.

When gold or ſilver is melted with a ſtrong heat; if they have any mixture of another metal, that other metal will be ſeen to burn upon its ſurface. Now it is to be obſerved of metals and their calxes, that melted metals mix with each other, but not with other ſubſtances. For inſtance, if ſand, earth or ſtones be put into melted lead, they do not at all incorporate with it; but when the calx of lead or of any other metal is melted, it then unites freely with theſe earthy ſubſtances, but not with any metal, not even with its own. Iron indeed being in ſome meaſure of an earthy ſubſtance joins more with ſuch ſubſtances than other metals: this is the reaſon, that melted glaſs will ſtick to this metal, though to no other.

Thus, when unfine gold or ſilver is melted, the metal mixt with them, as faſt as it burns to droſs, ſeparates from them. However lead vitrifying much more eaſily than any other metal, if this is mixt with the unfine ſilver or gold in a large proportion; while it burns from them, it carries

carries away all other base metals much more effectually than otherwise could well be done.

But the first thing necessary, in burning lead into litharge, is to provide a proper vessel to contain it. The only materials, fit for this purpose, are some kind of ashes free from any salts, such as the ashes of burnt bones, or of vegetables, after their salts have been perfectly extracted. The ashes of burnt bones are mostly used. If the vessel, wherein the lead is put, were made of any other materials, they being more easily vitrifiable, would be melted down by the lead, and let out the metal.

The refiners prepare a vessel with these ashes after this manner: they ram them hard into an oval iron ring, and by scraping out a cavity form a kind of shallow dish. This they call a test, it is also called a cupel. This test they place under a chimney, where a large double pair of bellows are fitted so, as to blow close over it. Into the cavity of this test they put their metal together with a little charcoal to begin the fire; over all they lay large billets of oak; which, taking fire, burn all the time of the operation. They prefer oak to other wood, because it will burn longer, before it is consumed. When the metal is upon the point of melting, they put in lead upon the metal. Upon the approach of

the lead, both metals ſoon melt down together, and by the intenſeneſs of the heat the lead burns up to litharge. In a ſmaller heat lead would have a droſs gather in a ſkin upon the top of it; but in this great heat the droſs melts, and flows like drops of oil upon the metal. This is litharge. On the ſide of the diſh oppoſite to the bellows is a hole pierced through, at which the litharge may paſs out, and as ſoon as the workman perceives litharge to riſe, he ſcrapes away a ſhallow channel in the teſt leading to this hole. The litharge, blown toward this channel by the bellows, paſſes off, and drops under the teſt. And this litharge carries away with it all baſe metal, wherewith the ſilver or gold may have been mixt.

Silver and gold are refined in eſſays after the ſame manner. Here it is uſual to put the ſilver or gold to be tried upon a ſmall teſt made with the aſhes of bones or horns, and place it either ſo, that the flame of a wind-furnace may draw over it, and conſume the lead melted with it, or elſe to place the teſt under a veſſel, we formerly deſcribed, called a muffle, and heap charcoal over it in a furnace uſually made of iron, and called from this office of it an eſſay-furnace. This furnace we have before deſcribed, and now we ſhall ſee the manner of uſing it.

In

In this operation the litharge ſoaks into the teſt.

Teſts are made of bone-aſhes in the greater works, becauſe they are a material, which will contain the lead long enough without vitrifying. But theſe aſhes are adapted for eſſays upon another account alſo. They adhere together but loſely; by which means the veſſel is a porous body, fitted to imbibe the litharge, as it is formed. Some compoſe eſſay-teſts of wood-aſhes carefully waſhed from their alkaline ſalt, only covering the cavity with bone-aſhes, and theſe teſts are more porous than the other, whereby they ſhorten the operation; but theſe dry leſs perfectly than thoſe of bone-aſhes, and therefore require much longer annealing, before the lead is put into them. Though theſe veſſels of whatever material they are made, ſhould be well heated before the operation: for as long as any moiſture remains in them, they will throw up particles of lead, which often fall out of the veſſel, and by carrying a proportional part of the ſilver with them falſify the eſſay.

In theſe eſſays it is neceſſary to make uſe of a quantity of lead, amounting at leaſt to eight times the weight of the metal to be refined, if it contain about a twelfth part of baſe metal; and

if it be coarſer, a greater quantity of lead muſt be added.

If gold and ſilver are mixt together, after they are purified by lead from all other mixture, the eſſay is finiſhed with aqua fortis, as we ſhall ſhew hereafter.

I have already hinted, that the uſe of lead in refining ſilver and gold ariſes from its eaſy vitrification, whereas the other metals, if alone, vitrify with difficulty; but when mixt with a large portion of lead, they are divided into ſo minute parts, that the fire operates more ſtrongly upon them. By this means copper, the metal moſt uſually mixt with ſilver, will vitrify, and paſs away with the litharge, whether the litharge be blown off, as in the greater operations, or it be ſoakt up by the teſt, as in eſſays.

Iron will not mix with lead, and therefore is quickly ſeparated, lying upon the top of the lead, and there waſting.

Tin is moſt difficult to free from ſilver, and more ſo from gold. This ariſes from its reſiſtance to vitrification. I have taken notice, that the burning-glaſs, which vitrified gold, would not produce that effect perfectly upon tin. For this reaſon the tin riſes preſently upon the lead in the form of droſs, and there will lie without

burning away. And in this condition is not ſo perfectly calcined, but that it holds yet a portion of the ſilver or gold adhering to it.

The moſt effectual method of performing this ſeparation is to mix the maſs with twice as much copper, as there may be of tin in the compoſition, and when the tin riſes upon the lead to take it off, and mixing it with glaſs of lead to proceed with it, as in eſſaying an ore.

The greateſt part of lead ores contain a portion of ſilver. This melts out from the ore with the lead; and is often in ſo large a quantity, as to be extracted to profit. In this country, where foſſil coals are uſed in the lead works, the operation is performed in this manner. A teſt of the ſame form, and made of the ſame materials, as that employed by the refiners of ſilver, but much larger, is placed in a furnace, where the flame of the fire draws over it, by the heat whereof the lead is burnt into litharge, which is drove to one end of the teſt by the blaſt of large double bellows, that blow conſtantly over the ſurface of the lead; and here the litharge falls out of the teſt by a hole cut through it for that purpoſe, as in the refining of ſilver before deſcribed. And as the lead waſtes, whereby it would fall too much below this hole for the litharge to paſs into it, they ſupply the lead from time to

time moſt uſually by thruſting in the end of a bar of lead, which melting, as it comes over the lead, ſupplies, the waſte of it.

There not being a demand for all the litharge made, the greateſt part of it is reduced into lead again by this means. The litharge is put into a reverberatory furnace, like that, we ſhall hereafter deſcribe, wherein the ores of lead, and other metals are ſmelted, and being ſpread abroad is covered with ſmall coals. Then it is heated for ſome time; after this it is ſtirred up, and more coals being thrown on, is heated for ſome time longer; by this means all the litharge will have changed its form, and lead be found in the furnace in its ſtead. Where ores are ſmelted with charcoal, they reduce litharge by throwing it into a melting-furnace mixt with charcoal as in ſmelting ores. The charcoal reduces it. In theſe places the lead is burnt into litharge by putting the lead into a ſhallow bed made of bone-aſhes laid over a large hearth built of brick or ſtone. To the bed an iron cover is fitted, and they melt, and burn the lead by wooden billets, which are thruſt in over the lead, and the blaſt of the ſame bellows both maintains the fire, and directs the litharge to its exit.

If silver be mixt with a large quantity of copper, which often happens in the mines of Germany, where many ores are found containing both metals; there is a method of separating them without destroying either metal. This is by melting down the composition with a quantity of lead, and then exposing the mixture to such a heat, as shall melt down the lead without melting the copper. By this means the lead will run from the copper, and carry the silver out along with it.

This is performed in a furnace of a particular make. This furnace is a long concave floor, with a channel running lengthwise through the middle of it. Cakes of the mixt metal are laid upon this floor, and, as the metal heats, the lead melts down into the channel underneath, and thence runs out into a bason made to receive it.

LECTURE XXIII.

BEFORE we take leave of the effects of fire upon the metals, and metallic bodies, it will not be improper to follow them into the ſhops of artificers, and make a few remarks upon ſome of the operations, which they there undergo. But we muſt firſt take into conſideration two eminent changes wrought on two of the metals, before they come into the artificer's hands: I mean the converting copper into braſs, and iron into ſteel.

Copper is made braſs with a mineral called calamy or lapis calaminaris. This mineral is firſt calcined, that is, heated red-hot in the fire, but no more. Then it is powdered, and mixed with twice its meaſure of charcoal-duſt. In this mixture is ſet edge-wiſe pieces of copper-plates to the amount of two-thirds of the weight of the calamy. This mixture is heated together for ſome time; at length the heat is made ſo ſtrong as to melt the copper. As ſoon as that is done, it becomes braſs, and is increaſed in weight. One hundred pounds of copper produces one hundred and forty pounds of braſs. If the copper

copper be more minutely divided, it will imbibe more of the calamy, and acquire a farther increaſe in weight. For this reaſon ſome granulate their copper, by pouring it melted into water. The braſs is caſt out into ſheets between ſtones. The only ſtones once uſed here for theſe moulds were brought from France, being dug from a quarry near St. Malo's. But ſince ſtones found in Cornwall have come into uſe for this purpoſe. The ſtones are firſt ſpread over with loam and horſe-dung, and kept by iron bars at the proper diſtance to make the mould.

The reaſon aſſigned for the neceſſity of caſting ſheet-braſs in theſe particular kinds of ſtones only, is, both that the loam adheres to them better, than it would to many other ſtones; and they are alſo thought to be capable of giving ſome vent to the fume, which riſes from melted braſs.

Braſs, if made of good copper, is very malleable; but when made of coarſe copper, will ſcarce endure the hammer.

In the making of braſs, if there be added to the other ingredients a quantity of old braſs kettles, that have been long in uſe, and often heated, the metal will be firmer. Without this addi-

addition the braſs cannot be made tough enough to draw out into fine wire.

The beſt copper for making braſs is that, which has been refined ſomething farther than would render it moſt malleable; when the copper in the phraſe of workmen is a little dry. Braſs, by being kept a length of time red-hot, will return to copper again.

The operation upon iron, whereby it is converted into ſteel, is a more uſeful invention than this of making braſs. This is variouſly deſcribed. Agricola ſays, it is done by ſoaking wrought bars of iron for ſome time in fuſible iron melted with the addition of a flux, that melts it more freely, and then immediately plunging them in water. In this laſt part of the operation, I ſuſpect, he confounds the making of ſteel with the method of hardening it. Steel is not diſtinguiſhed from iron by its being hard, but by its diſpoſition to be hardened upon being quenched in water, when red-hot, which is not the quality of iron. Some writers ſay, ſteel is prepared with the aſſiſtance of the hoofs and horns of animals. There is a method in uſe analagous to this of giving the hardneſs of ſteel to the outſide of iron by covering it over with the ſhavings of horns or hoofs and quenching it,

when hot, in water. After this operation a file will not touch the outer surface of the iron, though the iron within remain soft. In the method practised in England for making steel, nothing is added to the iron but powdered charcoal.

Iron bars are put into pots made in the form of an oblong square. The bottom of the pot is first covered with charcoal-dust, then the bars are laid in rows at some distance from each other, and being covered with charcoal-dust, other bars are laid in this stratification being continued till the pot is sufficiently filled: then the whole mass of bars is covered with charcoal, and sand strewed over all, to prevent the charcoal from taking fire. Each furnace contains three of these pots, the fire being between them, which is raised gradually, and one or more bars are so placed in the pots, that they can conveniently be pulled out from time to time; by which the heat of the fire is judged of; after a due time the fire is let down, and the bars taken out when cold, that they may not be wasted by scales. The bars, when converted into steel, are often found blistered on the outside.

Steel is of a more even texture than iron, and for that reason is preferred in fine works. But the chief property of steel, that distinguishes it

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from iron, is its growing exceeding hard by being quenched in water, when hot, ſo as to be fit for edge-tools, and be capable of cutting either iron or ſteel itſelf not ſo hardened.

If a piece of ſteel is made red-hot, and then ſuddenly quenched in cold water, it becomes hard and brittle like glaſs. This brittleneſs is diminiſhed by heating the ſteel again. But here a ſmall degree of heat only is to be given to the ſteel, and that different, according to the purpoſes for which the ſteel is intended. In order to judge of the degree of heat the ſteel is now to receive, the workmen rub it bright, and eſtimate the heat by the colours, which ariſe upon it. At firſt it turns a little yellowiſh, then of a deeper colour, and at length blue. The firſt colour, before it becomes deep, is the proper colour for gravers, files, drills, maſons chiſſels, razors, lancets, pen-knives, &c. for carpenters tools, that cut wood, the heat may continue till the colour be a little deeper, as alſo for the tools wherewith ſcrews are made. If it be heated till in the dark it look of a very dull red, and no longer, it is a ſpring. Farther heated than this, it becomes ſoft again. In this temper ſteel is the firmeſt to reſiſt any force. When harder than this, it is more or leſs brittle; when ſofter, it will give way, and bend with leſs

force.

force. For this reaſon the tools, that carpenters, and others uſe to turn ſcrews with, are made of ſteel ſet to this temper, or rather left in a ſmall degree harder. This ſpring-temper may be given to ſteel another way; by putting the ſteel, after it has been hardened, into oil, and heating the oil over a fire till it flames; then the ſteel taken out will have acquired a ſpring-temper. The moſt common method uſed by workmen in making a ſpring, is to heat it a little over a fire, then rub tallow upon it, and hold it again over the fire, till the tallow flames. But this method is not ſo ſecure as thoſe, I have now deſcribed. Springs have very often a blue colour given them for ornament. This is done after the ſpring is made, by brightening it, and then heating it, till it acquires this colour. This practice has occaſioned Mr. Boyle and others to miſtake, and conclude, that the degree of heat, whereby hardened ſteel is brought to this colour, makes it a ſpring; but with this heat alone it will be too brittle.

If a ſpring, after it is made, happens not to ſtand bent quite according to the deſign of the workman; by bending it forcibly into the deſired form, and in that ſhape heating it, till it become blue, and keeping it thus till cold, the

ſpring will retain the ſhape given it, without loſing any of its ſtrength as a ſpring; it will rather be ſtiffer. This is an artifice very neceſſary to the watch-makers. The axes of watch-wheels are made of ſteel wire ſet to a ſpring-temper. They firſt turn them nearly true, then harden and temper them. But ſteel in hardening is very apt to crook. When this accident happens in their work, they muſt proceed, and give the ſpring its temper, before they can ſtraighten it again. When it is brought to a ſpring-temper, they ſtrike gently upon the hollow ſide of it with an edged hammer. The hammer by cutting into the ſteel ſtretches out the hollow ſide, till the work becomes ſtraight. Then they blue it, and when cold turn off the cuts without any fear of it returning to its firſt ſhape. But if the ſteel does not keep perfectly ſtraight, the proceſs repeated a ſecond time is ſure to rectify it fully.

When it is neceſſary for harder ſteel to retain its figure exactly, they firſt unite the ſteel to iron, that no greater part of the inſtrument be ſteel, than where the hardneſs is required. Then, if the ſteel has any thing altered its figure in hardening, after it is brought to its temper, they can bring it back to its figure by ſome blows of a common hammer; for the iron will

give

give way, and hinder the ſteel from ſpringing back again, and the ſteel how hard ſoever, will bend without breaking, as much as is ordinarily required in this caſe.

Steel is more ſubject to crook thus in hardening, when over-heated. Care ſhould be taken to eſtimate rightly the degree of heat in giving ſteel its firſt hardneſs upon another account alſo: for if the heat be too ſmall, the ſteel will not be hard; if it be too great, the ſteel will become ſo brittle as never to recover a proper degree of toughneſs. It is better to fall ſhort in this heat than exceed; for, if the heat be not ſtrong enough for the ſteel to be hard, the proceſs may be repeated over again without damage to the ſteel; but if the ſteel be over-heated it is ſpoiled.

Steel ſhould not be forged with quite ſo great a heat as iron.

Thoſe, who make files, uſe an artifice, whereby they harden great numbers at once. They have an iron pipe and a rod, that fits it. They wrap up in wet loam a great bundle of files with this pipe in the middle, and by drawing out the rod from time to time, they judge of the heat of the whole bundle. The diſpoſition of the ſteel to harden by the ſudden application of cold to it, when hot, makes a particular management neceſſary, when it is deſired to have cold

ſteel

steel as soft as possible. For this purpose, when it is heated of a dullish red, they bury it up immediately in hot ashes, and there let it cool. Thus by keeping the hot steel from the contact of the cold air, it will be softer, and cut better either under the file or graver than otherwise. This is called annealing it.

I shall next consider the compositions usually made with metals.

Silver and gold when pure, are so soft, that hardening them in some degree is convenient to fit them better for the uses, to which they are put, either for coin or plate. Silver is thus hardened by a small mixture of copper; gold by copper or silver or by both together. In our mint copper is the metal used. The metal thus added is called the alloy. By standard silver, and gold is meant those metals with that portion of alloy, which is allowed by law.

The standard for our silver coin was most anciently eighteen penny-weights troy of alloy to eleven ounces and two penny-weights of fine silver: and the same standard is in use at this day. This is three parts in forty of the whole in alloy, that is near one thirteenth. Some years past it was enacted, that all wrought plate should be finer, and not have more than half an ounce of alloy in a pound of the whole. This is called

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the new ſtandard. This regulation was conceived to be a means to hinder the ſilver coin from being melted down by the ſilver-ſmiths. But a portion of fine ſilver mixt with the ſtandard of the coin will readily reduce it to the new ſtandard. And as this ſmall alloy leaves the plate too ſoft, it has ſince been made lawful to make plate of either ſtandard.

The ancienteſt ſtandard for gold was no more than one part in one hundred and ninety-two of the whole in alloy. In the firſt year of Henry the eighth ſome ſpecies of gold coin had one-twelfth of the whole in alloy: and from the reign of king Charles the ſecond, when guineas were firſt coined, all our gold money has this alloy. In the reign of Henry the eighth and Edward the ſixth we had both gold and ſilver coins made of much baſer metal than the preſent ſtandard, and varied with ſuch irregularity, that in one of the coinages of Edward the ſixth in exchanging gold coin for ſilver a man would not receive above double the weight of his gold in pure ſilver.

Copper by a mixture of tin makes the metal for bells and for what are called braſs cannon. For bells one part of tin for four of copper, but for cannon not above half ſo much tin is uſed. Bells are rendered yet more ſonorous by the ad-

dition of a little ſpelter. This compoſition is made uſe of in the fine bells of ſtriking-watches.

It is remarkable, that tin, though itſelf a ſoft metal, greatly adds to the ſonorous quality of other metals. Tin mixt with twice its weight of lead compoſes the metal for organ pipes.

Lead mixt with copper in the proportion of one part of lead to four of copper makes, what is called pot-metal, uſeful in coarſe works. This metal is harder than copper, or even braſs.

Copper requires a great heat to keep it intirely fluid, ſo that, if it be melted ever ſo perfectly, it very ſoon congeals, after it is out of the furnace. For this reaſon it is ſcarce poſſible to caſt any great work of copper alone, eſpecially if the work has many inequalities in it. Statuaries therefore never attempt to caſt ſtatues in pure copper; but uſe always a more fluxile metal by compounding the copper with ſome other metal. Either braſs, tin or lead will anſwer this end; and theſe compoſitions are in general called by the name of bronze.

Braſs with ſpelter is the compoſition of Bath-metal.

Nine parts or more of tin with one of the regulus of antimony compoſes pewter.

Metals are alſo mixt to make ſolders, wherewith to join other metals together. It is required in ſolders, that they melt ſooner than the metal to be ſoldered, and that they approach as near as may be to the metal ſoldered in hardneſs, and colour.

Iron is uſually ſoldered with braſs alone.

Lead is ſoldered with a mixture of two parts lead with one of tin. The ſolder of the tin-men is equal parts of lead and tin; the other not approaching near enough to the tin in colour.

One part of braſs, and two of ſpelter make that, which is uſually called ſpelter-ſolder, wherewith iron, braſs and copper may be ſoldered together. This is the ſolder uſed by the braziers and copper-ſmiths. This ſolder is improved, by adding to each ounce of it one penny-weight of ſilver. This ſolder melts not without a conſiderable degree of heat. Therefore this ſolder cannot be uſed, where it is inconvenient to heat the work red-hot. In this caſe therefore copper and braſs are ſoldered with pewter.

Two parts of ſilver and one of braſs will melt ſooner than either ſilver or braſs, and therefore is uſed in ſoldering either of theſe metals. This is uſually called ſilver-ſolder. This ſolder is

uſed to ſolder pieces of braſs together, by thoſe who make the finer kind of works in braſs.

Both ſilver and gold melt ſooner by having more alloy, and therefore by a ſolder of ſuch a compoſition may be ſoldered. The nearer the ſolder comes in fineneſs to the metal, the greater care is required, that the work melt not in ſoldering: but the nearer will the ſolder approach to the work in colour.

The pewterers uſe a kind of ſolder made with two parts of tin and one of biſmuth. This compoſition melts with the leaſt heat of any of the ſolders.

But in ſoldering ſome artifice is neceſſary to make the ſolder and metals adhere.

All the metals except ſilver and gold upon melting, or before, are covered over with droſs; and all the ſolders have ſome of theſe metals in them. This droſs hinders the ſolder and metal from uniting; for I have already obſerved, that metals unite eaſily with each other, but not with their droſs. Therefore it is neceſſary, that this droſs be removed. This is not performed in all ſoldering by the ſame materials.

The plumbers effect this with greaſe. They firſt greaſe their lead, where they deſign the ſolder to adhere, then lay the ſolder on and melt it with

with a hot iron. What droſs, the melting generates, unites with the greaſe and flows away from off the melted metal. The glaziers and tin-men uſe roſin in powder for the ſame purpoſe; for all inflammable ſubſtances, that will melt, are equally conducive to this uſe. I have before obſerved, that the droſſes of metals, when vitrified, ſeparate clean from the metal; but before, while leſs perfectly calcined they adhere a little. Now theſe ſubſtances, that in a proper degree of heat, will reduce the calxes of metals back to their metallic form, in a leſs heat, will ſo join with the calx as to cauſe it to ſeparate clean from the metal.

Always in ſoldering the metals muſt be made very bright, where the ſolder is to take hold of them: for any dirt or ſoil will prevent the adheſion.

Analagous to this method of ſoldering is that, whereby iron plates are covered over with tin; for making the tin ware ſo much in uſe.

In Germany theſe plates are hammered out under a large hammer. The hammer is a very heavy one, lifted by a water-wheel, and the plates are not brought under it ſingle, but a great number together; and that each may receive an equal battering from the hammer, they

are continually ſhifted among one another by the workman, that holds them to the hammer, whereby each in its turn only receives the immediate blow of the hammer. In England we roll them out, when red hot, by a mill between iron rollers.

These plates are ſcoured bright with ſand, being firſt ſoakt in a weak kind of vinegar, then are dipt into a pot of melted tin covered over with fat; ſo that the plate paſſes through the fat in going into the tin. When the plate is drawn up a thin covering of tin adheres to it. The fat is fitteſt for the purpoſe, when it has been firſt fried black, whereby a part of its watry humidity has been evaporated.

Copper and braſs are covered over with tin by the help of another material, ſal ammoniac, which alſo contains ſome portion of an inflammable ſubſtance, for thrown on nitre it flames.

The copper or braſs being made hot enough to melt tin laid upon it, is ſtrewed over with ſal ammoniac, and the melted tin rubbed about the plate. The ſal ammoniac licks up the droſs of the tin, and leaves the tin to flow freely upon the metal. The ſame material is uſed, when copper or braſs is ſoldered with pewter. The work is firſt waſhed with a ſolution of ſal ammo-

niac

niac in water; then heated just hot enough to melt the pewter, and the pewter applied to the joint to be soldered.

In soldering, that requires a greater heat, borax is the material used. In this case the borax by a great heat melting into a kind of glass unites with the dross of the solder or the other metals, and separates it clean from the metal.

Silver and gold produce no dross in our fires; gold therefore can be joined to silver with heat only without any medium. Thus silver bars are gilt, before they are drawn into wire. Thin leaves of gold are spread out upon a table, the bar of silver made pretty hot is rolled upon them, and they adhere. Then the bar is heated red hot, and rubbed, till it is cold, with smooth stones. After this the gold adheres so firmly, that it never leaves the surface of the silver, though the bar above an inch thick is drawn out into an exceeding small wire. Dr. Halley has computed, that the gilding will be thus extended upon silver wire, till it be less than one-hundred-thousandth part of an inch thick.

Among the mixtures made with metals must be reckoned the amalgamating them with quicksilver. This metal will unite itself with all the rest, except iron; though not very freely with copper. Quicksilver will unite with so much of

the other metal, as to form a ſoft conſiſtence between the fluidity of quickſilver and the ſolidity of the other metal. All theſe compoſitions are called amalgamas.

The facility, wherewith quickſilver unites with lead, has given occaſion to the adulterating it with that metal. To make an amalgama expeditiouſly it is only neceſſary to heat the quickſilver, and either melt the other metal, or at leaſt make it red-hot; and then to pour on the quickſilver. But the moſt convenient method for gold, ſilver, and copper is to diſſolve the metals in an acid ſpirit, and then precipitate them again by another metal capable of producing that effect. By this means the metal will be reduced into more ſubtle parts than by any other method whatever; and quickſilver will then very readily unite itſelf with the other metal.

However quickſilver will unite itſelf, though not ſo expeditiouſly, with lead, tin, gold, or ſilver, if any of thoſe metals are put into it cold. Looking-glaſſes are covered over with an amalgama of quick-ſilver and tin. A thin ſheet of tin is firſt ſpread out upon a flat marble laid to a true level. Theſe ſheets of tin are hammered out under a heavy hammer, as the iron plates are hammered out for tinning. They are not thicker

than

than the thickeſt ſort of whited brown paper. Upon ſuch a ſheet of tin ſpread out they pour a little quickſilver and with a cloth and hare's foot ſpread it equally over the tin. Then they pour more quickſilver on, and with an even hand ſlide the glaſs over it. As ſoon as this is done, they ſet two or three braſs weights about the glaſs to keep it ſteady, and then incline the marble for all the uſeleſs quickſilver to run off. In the laſt place the glaſs is covered over with weights, of about ſeven pounds a-piece, as cloſe as they can ſtand by each other. In three hours time the foil adheres firmly to the glaſs.

I have a little before obſerved, that ſilver might be gilt by barely laying on leaf-gold upon it and rubbing it hard on, the ſilver being made red-hot. In works, where ſuch heating and forcible rubbing are not proper, the gilding is performed with an amalgama of gold and quickſilver; this being ſpread over the ſilver, and then the ſilver heated in a ſmall degree, that the quickſilver evaporate, the gold will remain behind, and with a burniſher is rubbed ſmooth. A burniſher is only a piece of ſteel ſet to the temper fit for the hardeſt edge-tool, and poliſhed very ſmooth.

Thus

Thus are gilt both ſilver and braſs. There is another artifice of giving braſs a golden colour, called lackering. This is done by paſſing over the braſs, when a little warm, a bruſh dipt in a ſolution of gum lac in ſpirit of wine tinctured by ſome material that ſhall give it the deſired colour.

LEC-

LECTURE XXIV.

THE CONCLUSION.

WE have now gone through the operations of chemiſtry upon the ſeveral ſubjects, that come under its cognizance, by which we may obſerve the great extent of the art. It takes under conſideration all parts of the creation, that are within our reach to operate upon.

We may farther learn this from the whole, that the powers of nature, by which its operations are performed in the ſmall parts of matter, are very few and ſimple.

The firſt operations of chemiſtry purſue the analyſis of bodies, till the moſt compound are reduced to five principles, water, ſpirit, oil, ſalts, and earth. A more careful examination has indeed diſcovered a ſixth, a vapour ſimilar to the air we breathe. But moſt of theſe are found to be compound ſubſtances, and may be reduced to a ſmaller number of principles.

The

The ſpirit and ſalt are only ſome active power, joined to one of the other principles. Salts are only ſome active power joined with an earth; ſpirits ſome active power joined with water. This power we have found, when joined with water only, to appear under the form of an acid. But the vinous ſpirit is here to be excepted. This ſpirit partakes more of the nature of an oil.

Oils part viſibly into earth, and ſpirit or water. At the ſame time they loſe a portion of air, and ceaſe to be inflammable. The air therefore is either the principle, which renders them inflammable, or ſeparates them from the reſt by the expulſion of the inflammable principle. At the moſt therefore oils are diviſible into four principles, three of which are the ſame, as are found in other ſubſtances.

There are other ſubſtances, in which this principle of inflammability is found, that are ſome of them no leſs, others more ſimple than oils. All vegetable and animal ſubſtances are reduced by diſtillation to a black coal, wherein this inflammable ſubſtance is united with earth and a ſalt, or with earth alone. The vinous ſpirit ſeems to be this inflammable ſubſtance united with water; for if it be burnt ſlowly

under

under a bell, as sulphur is burnt to obtain its acid spirit, a considerable quantity of water will be collected, and no inflammable spirit. With the small heat of distillation scarce any air separates from it. But if it be boiled, air separates. This is most commodiously tried by a glass in the form of a thermometer; for if the spirit in the ball be caused to boil, there is always found upon its cooling a bubble of air in the ball.

This inflammable substance is in bodies, that do not burn. We have shewn it beyond contradiction to be in metals. And, if we consider Mr. Boyle's experiment upon water, whereby he reduced it to a dry earth, (that is, calcined it like a metal) we cannot doubt, but that water is held fluid by the same principle, as renders metals fluxible with a due degree of heat. One of them, quicksilver, remains fluid with less heat than will keep water so, and requires a gentle heat to calcine it, as water does. I am informed, that water has been calcined in a close vessel, by standing a long time in a moderate heat, much after the manner, as quicksilver is calcined, only with this difference, that no access of air at all must be allowed the water, lest it should evaporate. Mr. Boyle's method

of

of converting water into earth is by repeated distillations.

Upon these considerations we may conclude, that the bulk of all bodies consists of particles of matter, in different bodies diversely figured and composed, which of themselves are unactive. These we may call terrestrious or earthy parts. These appear to be actuated by two principles at most, the acid, and the inflammable principle. This last we shall call sulphur; as I apprehend this to be the meaning of the word, when used with propriety in its philosophical sense, though no word has been more loosely used by writers than this.

We find the presence of this sulphur necessary to the form of bodies. Metals, when divested of a due portion of it by calcination, lose their metallic form; animal and vegetable substances, till deprived of this principle retain their organic structure; but no longer.

Farther, sir Isaac Newton, in his treatise of Optics, gives reasons for concluding, that bodies act more or less upon light in refracting and reflecting it, in proportion as they abound with sulphur. Sulphureous bodies also soonest grow hot. Now as heat dilates bodies, and at length separates their parts, dissipating the body in smoke,

ſmoke, we may conſider ſulphur as the author of the repelling force found in bodies; for this repelling force depends upon heat, which operates moſt immediately upon the ſulphur of bodies, as we have juſt now ſaid. Even the expanſion of the air depends upon its heat.

Thus ſulphur by the mediation of heat is the author of the repulſive force ſeen in nature, which is one cauſe of the changes, bodies undergo in the courſe of things: the other is the acid principle. The particular power of this ſeems to be the uniting other parts of matter with water; whereby the component parts of bodies are transferred from place to place, and the whole œconomy of nature in the reciprocal reſolution and renovation of all ſublunery beings is throughout the courſe of time carried on.

Theſe are the general deductions to be drawn from the operations of chemiſtry.

I ſhall now put a concluſion to this Courſe by ſome particular remarks, that have not yet fallen in our way.

In the courſe of theſe lectures we have had occaſion to take notice of ſome changes made in the taſte, ſmell, and colour of bodies by the means of ſpirits and ſalts. Silver diſſolved in ſpirit of nitre acquires an extreme bitter taſte, lead a ſweet one,

one, whether diſſolved in ſpirit of nitre or in vinegar. Sulphur diſſolved in water either by the help of lime or of an alkaline ſalt, upon the affuſion of an acid ſpirit ſends forth at once a ſmell extremely fetid reſembling that of rotten eggs; and changes from its red tincture to a white one.

But what relates to colours has not been yet conſidered ſo fully as the ſubject deſerves. The painters, dyers, and the workers in glaſs have received great aſſiſtance in their colours from the art of chemiſtry.

Glaſs is coloured chiefly by metals or metalline ſubſtances, theſe induring the ſtrongeſt fires. It is coloured yellow indeed by a vegetable ſubſtance, bran. But this glaſs muſt not remain very long in the fire. It is tinged blue by the mineral ſubſtance before deſcribed with arſenic called zaffora or zaphor, of a ſky-colour by calcined copper, green by calcined iron, and red by gold diſſolved in aqua regia. There muſt be put a little common ſalt into the glaſs along with the gold prepared as above, otherwiſe they will not unite. There is a remarkable incident occurs in working this colour. That the glaſs, when firſt taken up and blown, appears tranſparent like other glaſs, but by being often put into the furnace and drawn out, the tinging particles

ticles gradually assemble together, and give a colour to the glass. Silver is of no use in this art. It gives glass a yellow colour indeed but of a disagreeable hue. Glass is tinctured black by magnese, the substance wherewith they take off its green colour. This substance in a small quantity only removes the green hue natural to glass; but in a larger proportion dies it purple, and if this purple is very intense, it appears black.

The painters owe to white lead the ground of their art. It is their white. This calcined for a time turns yellow and is called masticot. They have been of late indebted to chemistry for a very necessary colour the Prussian blue. Their best black is the coal of an animal substance calcined. Ivory-black is ivory calcined.

The dyers also make a very general use of alum and tartar; therefore the reason for the fundamental work of their art is to be taken from chemistry. Their colours are chiefly extracted from vegetables, disposed to tinge water of each colour. And their tinctures are prepared without any particular artifice except in woad. This vegetable after it is gathered, is moistened and pressed together, that it may heat, then dried, and the same process repeated two or three times. An infusion of this by a mixture of

lime will ſlowly ferment. During the fermentation it dyes a blue colour. Alone it makes only a ſky-blue, but with a proper addition of indico, the inſpiſſated juice of a ſimilar plant, the colour may be deepened to any degree. The cloth comes green out of the liquor; but by the contact of the air turns immediately blue. The fineſt ſcarlet is dyed with cochineal, now ſuppoſed to be an animal ſubſtance. To dye with this colour requires ſome acid ſpirit, as I have take notice before. But it muſt firſt have corroded tin, elſe it will deſtroy the cloth. There is alſo another circumſtance neceſſary. The dying muſt be performed in a tin or pewter veſſel. Should one of copper or iron be made uſe of, the ſpirit would quit the tin and act on the veſſel, and during that action would alſo corrode the cloth.

The dyers have no material of a black tint, wherewith to dye that colour. They dye that colour with copperas or the like ferrugineous ſubſtance, and with an aſtringent vegetable, uſually with galls. For an infuſion of galls, granate-bark, or any vegetable aſtringent in water added to a ſolution of copperas becomes immediately black. Common writing-ink is made by this means with the addition of a little gum to make it more ſtable upon the paper.

By

By this effect of vegetable astringents upon ferrugineous substances, medicinal waters are usually tried, how far they are to be esteemed of the chalybeate kind.

It is from the art of chemistry that we must learn the nature of mineral waters.

Waters, as they arise from the earth, are generally more or less tinctured with the vitriolic acid, which I have before observed to abound in the bowels of the earth. This acid is that, which hinders soap from dissolving in spring-waters: for all acids produce this effect in water. The water, which has ran long in the channel of a river, has met with substances, that imbibe this acid. In their passage under ground they also find some portion of calcarious and other substances, whereon the acid will operate: and as I observed formerly, that this acid acts stronger upon the alkaline salts, than on any other substances; so we may find, those salts generally make a precipitation from spring-waters. What precipitates is of the calcarious kind. The same incrustates vessels, wherein it is boiled. That crust well calcined heats and smokes upon the affusion of water like common lime.

If these waters find any metallic parts, that the acid will take up, the waters become medicinal. Some express great jealousies about these

waters, lest they ſhould contain lead, arſenical parts, or the like pernicious ingredients; but of all metallic ſubſtances, iron and copper only will be united with water by this acid. So that mineral waters can contain no metallic ſubſtances except iron or copper. Iron is the moſt common ingredient. Where there is copper the water has an emetic quality. Iron in theſe waters is diſcovered by the means, I mentioned before.

The greater part of theſe metallic waters have a ſprightly ſpirituous taſte, and ſparkle upon pouring out. It has much perplexed the enquirers into theſe waters to diſcover the original of this ſpirituouſneſs. If the water ſtands open, this quality is ſoon loſt. But if when taken from the ſpring it be immediately confined cloſe, it preſerves this ſpirit a great while, unleſs it chance to break the veſſel containing it.

There are waters furniſhed very eminently with this active ſpirit, that have no metallic parts in them. They do not therefore owe it to them. All theſe ſpirituous waters ſhew ſigns of being impregnated with alkaline parts. As I obſerved, that waters in the earth not only are charged with an acid, but meet alſo with calcarious parts, whereon the acid will act; theſe waters riſe out of the earth, before the fermenta-

tion is over, and the ſpirit found in them is no other, than what ariſes in fermentations. If the water is forcibly confined, that this ſpirituous vapour cannot expand itſelf, the fermentation is reſtrained, and the water kept in this fermentable condition a great while.

If theſe waters contain metallic parts the fermentation gradually deprives them of the acid, that kept them ſuſpended: for this reaſon, when chalybeate waters have loſt their ſpirit, the irony parts are found at the bottom in the form of oker.

When the fermentation has been ſtrong, the waters riſe warm.

FINIS.

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